#244

Kesterson Reservoir
2000 Biological Monitoring

Prepared for

U.S. Bureau of Reclamation Mid-Pacific Region

January 2001

CH2MHILL
CH2M HILL
2485 Natomas Park Drive, Suite 600
Sacramento, CA 95833

Kesterson Reservoir
2000 Biological Monitoring

Submitted to

U.S. Bureau of Reclamation Mid-Pacific Region

January 2001

CH2MHILL

Contents

Tables

Figures

SECTION 1

Introduction and Summary

Biological monitoring of Kesterson Reservoir has been conducted since 1987 in order to determine selenium concentrations in abiotic and biotic elements. In 1988, with the drying out of Kesterson and filling of low-lying areas, studies shifted to focus on the upland environment and the ephemeral pools that form during the rainy winter months. Selenium-caused effects to wildlife (such as embryo deformities, reduced egg viability, or mortality) have not been found during those studies although elevated selenium continues to be found in bird eggs and other wildlife. Based on aquatic bird toxicity data, the selenium chemistry data generally indicate a low-level risk of avian reproductive effects. However, due to the generally small numbers of breeding birds present at Kesterson, low-level effects would be difficult to detect. Based on the results of selenium monitoring at Kesterson since 1988, the U.S. Bureau of Reclamation (Reclamation), the Central Valley Regional Water Quality Control Board (RWQCB), U.S. Fish and Wildlife Service (Service), and CH2M HILL in 1995 agreed to change the monitoring program at Kesterson from annual comprehensive monitoring to more focused annual monitoring of selected biota that were judged to be at the highest risk, with more comprehensive sampling of biota every three years. The 1998 sample year was the first year that complete monitoring was conducted after the 1995 decision, and only limited sampling was conducted in 1999 and 2000 (as planned). The next planned comprehensive monitoring is to be conducted in 2001.

Figure 1–1 shows the cumulative rainfall for water years (July 1 to June 30) at Kesterson from 1989 through 2000. 1998 was an El Niño year and, therefore, an unusually wet year (Figure 1–1); rainfall and ephemeral pools persisted far into the growing season for plants and the breeding season for birds. The excess rainfall caused flooding and delayed plant growth and bird nesting as well as apparently reducing nesting success at Kesterson and other areas of California (A. Erichsen, University of California, Davis; R. Anderson, Swainson's Hawk Technical Action Committee; S. Buranek, National Park Service; personal communications). Shorebird nesting attempts at Kesterson were higher than any other year since 1988, in contrast to the low number of nesting attempts made by many terrestrial bird species.

Rainfall in 1999 and 2000 was lower than in 1998 and the area covered by rainwater pools was limited, with only a few pools persisting into March and April. There was little biological activity at these pools during the avian reproductive period and no bird nesting associated with the pools was observed. Killdeer (*Charadrius vociferus*)were the only shorebird species found nesting at Kesterson in both 1999 and 2000. During the 2000 nesting season (March–June), killdeer began nesting during the first part of March as in 1998, but in lower numbers (Figure 1–2A). However, terrestrial plants, invertebrates, and vertebrate prey items appeared to be abundant in both 1999 and 2000 (based on observations during monitoring). Cavity-nesting species studied (i.e., American kestrels [*Falco sparverius*] and barn owls [*Tyto alba*]) appeared to have similar success (as a percent of successful nests) from 1998 to 2000, whereas the cup-nesting terrestrial species studied (loggerhead shrikes [*Lanius ludovicianus*]) had greater success in 1999 and 2000 than in 1998. Generally, more

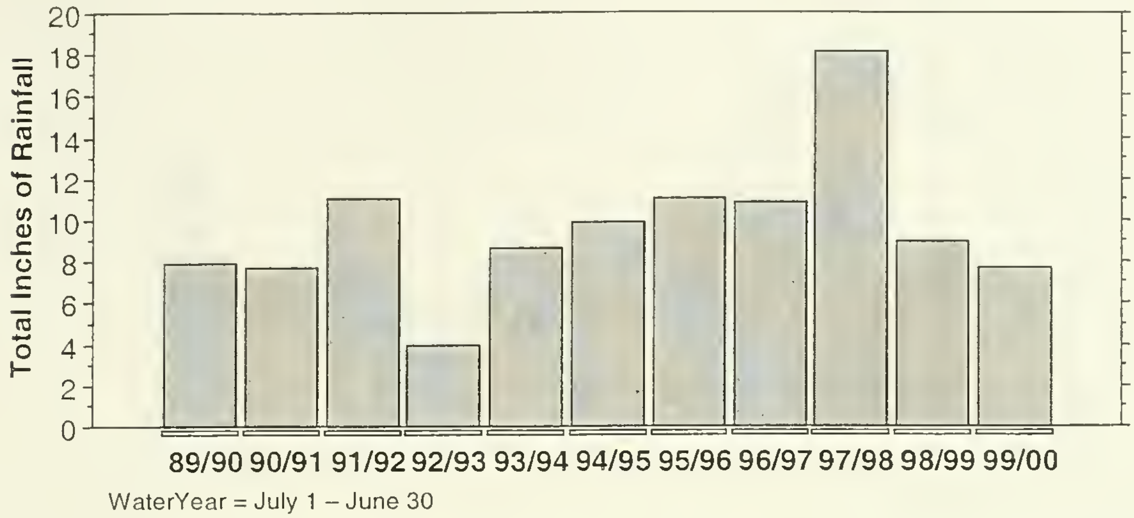


FIGURE 1-1
Kesterson Total Rainfall for Water Years from 1989 to 2000

terrestrial birds (i.e., raptors and passerines) were observed during the nesting season in 1999 than in 1998 or 2000. For example, when the numbers of raptors (i.e., all owls, hawks, and falcons) observed in 1999 are compared to other years, the numbers seen during the nesting season were higher than in all other monitoring years. During the wintering season (October–January) the numbers were similar (Figure 1–2B). The winter raptor surveys also suggest a possible 3- to 5-year cycle, based on red-tailed hawk (*Buteo jamaicensis*) surveys and small mammal trap success, probably driven by the cycling of prey populations (Figure 1–3). Other species populations may fluctuate according to food availability, weather, or other factors. Figure 1–2 also illustrates the differences between the abundance of different avian species both through the seasons and from year to year.

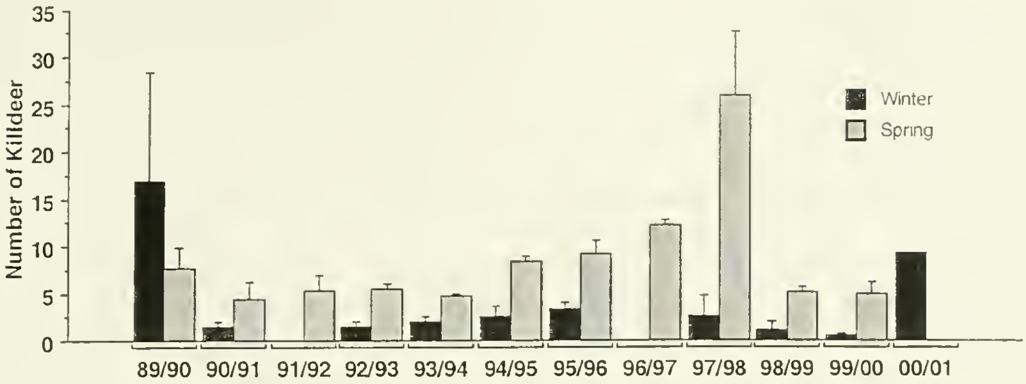
Following this introduction and summary of Kesterson biological monitoring for the year 2000 are detailed reports describing the following studies:

- Wildlife Surveys
- Ephemeral Pool Monitoring
- Bird Nesting and Reproduction
- Predatory Bird Nesting
- Selenium in Wild Birds

A brief summary of the year 2000 biological monitoring results is presented below.

1.1 Wildlife Surveys

In general, birds associated with wetland habitats (killdeer and other shorebirds) were found in similar numbers to what was found in 1999 and lower than the unusually high numbers observed in 1998. Raptor (i.e., owls, hawks, and falcons) numbers were lower



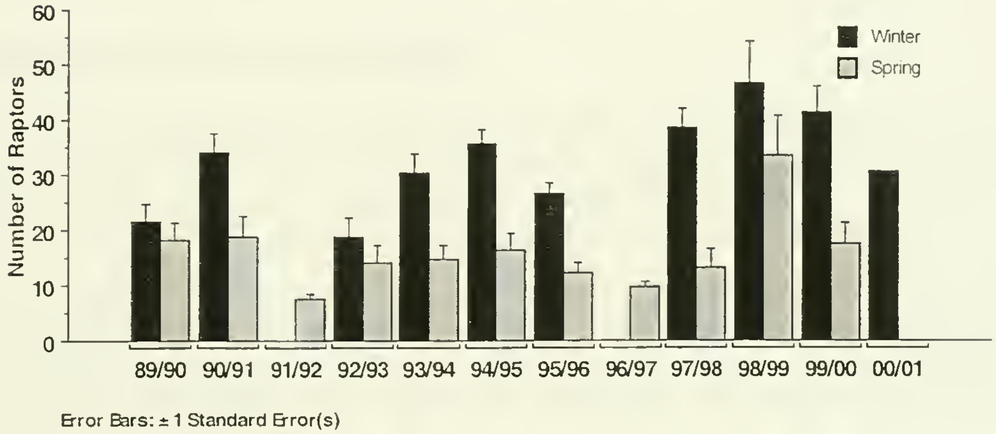


FIGURE 1-2 A & B

Average Number of (a) Killdeer and (b) Raptors (i.e., Owls, Hawks, and Falcons) Per Census Count Observed During the Wintering Season[a] (October–January) and the Spring Breeding Season (March–June).

[a] Only October survey results were available for the Winter, 2000.

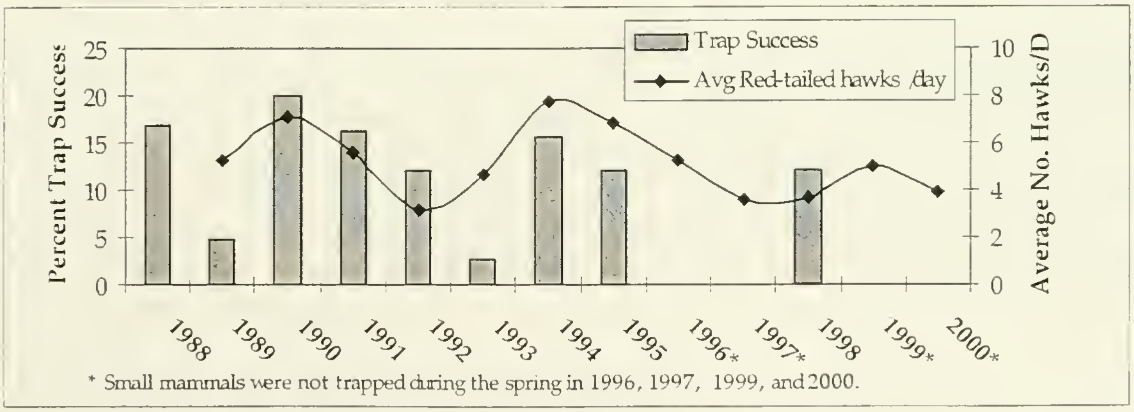


FIGURE 1-3

Red-tailed Hawk Average Annual Daily Use and Percent Small Mammal Trap Success

in 2000 than in 1999 but slightly higher than in other years. Terrestrial bird species, including blackbirds and European starlings (*Sturnus vulgaris*), were generally observed at lower numbers during the fall of 2000 than in 1998 and 1999 and western meadowlarks (*Sturnella neglecta*) had higher numbers than in 1999 and similar numbers to 1998. The numbers of sparrows counted in the fall decreased from 1997 to 1999 while the numbers counted in the spring increased in 1998 and have remained at higher numbers since then. Possibly the habitat changes at Kesterson, including greater shrub cover, have been partly responsible for the changes observed. Western meadowlarks counted during the fall of 1999 showed a decrease compared to counts in recent years although spring surveys indicate that their numbers are up from 1998 counts and down from 1999 counts. Other species appear to have been generally similar to the numbers observed in recent years. The surveys suggest that the numbers of terrestrial birds using Kesterson vary greatly from year-to-year, probably in response to factors such as weather, food availability, nest-site availability, and off-site conditions.

1.2 Ephemeral Pool Monitoring

A relatively small number of ephemeral pools formed at Kesterson during the winter and early spring of 1999–2000. Water and biota samples were collected from 11 pools located in 9 ponds and all 3 trisections. A total of 49 water samples and 30 biota samples were collected on March 7 or March 29, 2000 and analyzed for total selenium concentrations.

Water and invertebrate tissue selenium concentrations were significantly and positively related in the 2000 Kesterson ephemeral pools, as they have been in previous years. Pool water samples ranged from 1.9 to 247 μg/L selenium concentration (geometric mean of 33 μg/L), while aquatic invertebrate tissue concentrations ranged from 2.3 to 177 mg selenium/kg dry weight of tissue (geometric mean of 25.1 mg/kg).

Two assessments of potential food sources for aquatic invertebrates were performed in 2000. In the first, poolwater was filtered through 0.45 μm mesh filters to test for the relative abundance of particulate versus dissolved selenium. Water column particles are consumed by some of the aquatic invertebrates of the pools. Only one set of four pools tested had measurable particulate selenium, totaling about 6 percent of the total waterborne selenium concentration.

The second test involved measuring the selenium content of the attached algae, bacteria, and fungi (aufwuchs community) that colonized the surface of plastic films left for a month in several ponds. Aufwuchs organisms constitute a likely food source for many of the aquatic invertebrates. Aufwuchs tissue selenium concentrations varied in direct proportion to waterborne concentrations, ranging from 1.6 to 190 mg selenium/kg dry weight of tissue (geometric mean of 20.8 mg/kg). The aufwuchs community covers all surfaces in these small ponds and is the most likely direct dietary pathway from waterborne to invertebrate tissue concentrations of selenium.

1.3 Bird Nesting and Reproduction

Bird nest searches were conducted along access roads and interior areas of Kesterson as in other years. Eggs were collected and nests were monitored to determine success or failure.

One randomly selected egg was collected from each complete nest found. Eggs were collected early during the incubation period from most nests so that as many nests as possible would be sampled (i.e., few nests were not sampled due to predation of the nest prior to clutch completion). This provides a representation of selenium concentrations for the entire site and helps to identify possible hot spots for management or additional sampling. Collecting early during the incubation period may increase the proportion of eggs considered viable (i.e., fertile eggs or those with living embryos). This is because there is potentially higher embryo mortality later during incubation and embryo teratogenesis is more likely to be found in later-stage embryos. However, a study conducted in 1998 showed that this bias was not significant for Kesterson (Steven Detwiler, UC Davis, personal communication).

Generally, nesting by wetland-associated species was lower than in 1998 and nesting by terrestrial species was lower than in 1999. Although selenium levels in most eggs were elevated above background levels, no seleno-toxic effects were observed in 2000. Geometric mean selenium concentrations were similar among most species collected from Kesterson in 2000 and the overall mean selenium concentration was 3.2 $\mu g/g$ (Table 1–1). Overall success of nests that were found and monitored at Kesterson in 2000 was 37 percent, which is lower than the success in 1999 (58 percent) and similar to 1998 results (32 percent). Thirty-eight percent of all the nests found in 2000 were lost to predators and three percent were abandoned by the adults.

TABLE 1-1
Summary of Selenium Concentrations (μg/g dry weight) in Bird Eggs Collected from Kesterson Compared by Species, 2000

Species	*n*	Range	Geometric Mean[a]
American kestrel	4	2.7–3.5	2.9
Barn swallow	2	4.1–5.4	4.7
Barn owl	5	1.8–4.9	2.8
European starling	6	2.5–7.4	4.0
Killdeer	8	1.6–6.9	3.2
Western king bird	2	4.0–4.4	4.2
Loggerhead shrike	7	1.6–4.6	2.9
Ringed-necked pheasant	1	0.49	0.49
All eggs	***35***	***1.6–7.4***	***3.2***

[a] There was no statistically significant difference in Se concentrations among species ($F_{5,26}$=0.963, P = 0.458).

As in other years, there was a high percentage of nest predation, especially among ground-nesting species. The relative number of species nesting in any year likely changes due to a number of factors. Some of these factors are variations in climatic conditions (e.g., rainfall and temperature), conversion of Kesterson from a wetland to a terrestrial ecosystem, successional changes in vegetation causing plant species changes and structural changes in habitat, and disturbance during the reproductive season from monitoring and management activities.

1.4 Predatory Bird Nesting

Five of 30 nest boxes (15 percent occupancy) located on Kesterson and two off-site nest boxes (40 percent occupancy) were used by American kestrels. Five of six barn owl nest boxes were used during 2000. Seven loggerhead shrike nests containing eggs were found onsite and two were discovered along the San Luis Drain, south of Pond 1. American kestrel nest success onsite was 100 percent and offsite success was 50 percent. Barn owl nest success was 60 percent. Two barn owl nests failed possibly due to abandonment.

For kestrels and barn owls, an egg was collected from each of the nests and blood samples were collected from parents (if they could be captured at the nest). For kestrels, shrikes, and barn owls, a blood sample was collected from the young before they fledged. Blood-Se levels were variable in parent birds (kestrel, 2.7–14 $\mu g/g$; barn owl, 5.7–12 $\mu g/g$; and shrike, 7.0–11 $\mu g/g$ Se), and in their chicks (kestrel, 1.8–11 $\mu g/g$; barn owl, 4.0–6.1 $\mu g/g$; and shrikes 3.5–14 $\mu g/g$ Se) and less variable in eggs (kestrel, 2.0–3.5 $\mu g/g$; barn owl, 2.0-4.9 $\mu g/g$; and shrikes 1.6–4.6 $\mu g/g$ Se).

1.5 Selenium in Wild Birds

Wild terrestrial birds, primarily hawks, falcons, owls, and shrikes as well as a limited number of other species (killdeer, starlings, white-crowned sparrows [*Zonotrichia leucophrys*], western meadowlarks, and a western kingbird [*Tyrannus verticalis*]), were trapped and banded (with a federal band), or collected, and sampled (blood) from 1994–2000 to monitor selenium concentrations in terrestrial birds using Kesterson throughout the year.

While Kesterson was the focus of the sampling effort, other areas were sampled also as reference areas from 1994 to 2000. One reference area included lands surrounding Kesterson for an approximate 16-km radius (generally bounded by the cities of Stevinson, Gustine, Los Banos, and Santa Nella; referred to as Kesterson Area) that contained primarily agricultural lands (row crops, orchards, and pasture) and seasonal wetland habitats. Other study areas were located approximately 200 km north of Kesterson in the Sacramento Valley of California in the counties of Yolo, Solano, and San Joaquin (Sacramento Valley); and approximately 130 km northwest of Kesterson near Suisun Marsh (Bay–Delta). Except for the Bay–Delta study area, which was mostly wetland, habitats in these areas were mostly agricultural, similar to those of the Kesterson Area. Limited trapping for American kestrels was also conducted during November 1995 in agricultural areas adjacent to the Salton Sea, located in the Imperial Valley of California, approximately 1,100 km south of Kesterson. During 2000, only kestrels and shrikes were collected from reference areas.

Five hundred nineteen (519) individual adult birds were sampled (including 59 shrikes, 406 raptors, 8 meadowlarks, 33 starlings, 6 white-crowned sparrows, 1 kingbird, and 6 killdeer) from 1994–2000. Thirteen adult birds and 43 young were banded and sampled at Kesterson in 2000. Selenium concentration in blood was similar in loggerhead shrikes, kestrels, and barn owls but higher in the single nesting killdeer that was sampled (See Table 1-2). Blood-Se is an indicator of dietary exposure, and after about 35 days there is about a 1:1 ratio between diet and blood-Se in kestrels fed selenomethionine (Yamamoto et al. 1998). Therefore, blood levels probably reflect the average dietary exposure for these

individuals. As in other years, blood-Se was highly variable during all seasons but blood-Se in birds sampled during the spring breeding season was significantly higher than blood-Se sampled during the other seasons (Figure 1–4). This may be because the birds sampled during the spring are foraging over smaller ranges nearer their nests within Kesterson. All the birds trapped at Kesterson in 2000 appeared healthy based on visual examination and body weight (i.e., body weights were within the normal range for the gender and species).

TABLE 1-2
Blood-Se Concentrations (μg/g dry weight) in Wild Birds (adults and young) from Kesterson, 2000

Species	*n*	Range	Geometric Mean[a,b]
American kestrel	21	1.8 – 14	5.4
Barn owl	15	1.7–9.1	5.2
Loggerhead shrike	19	3.5–14	6.1
Killdeer	1	38	38
All 2000	***56***	***1.7–38***	***5.7***

[a] There was no statistically significant difference in Se concentrations among species ($F_{2,52}$=0.530, P = 0.592).
[b] Average percent moisture in blood samples was 82% (range = 73–86%).

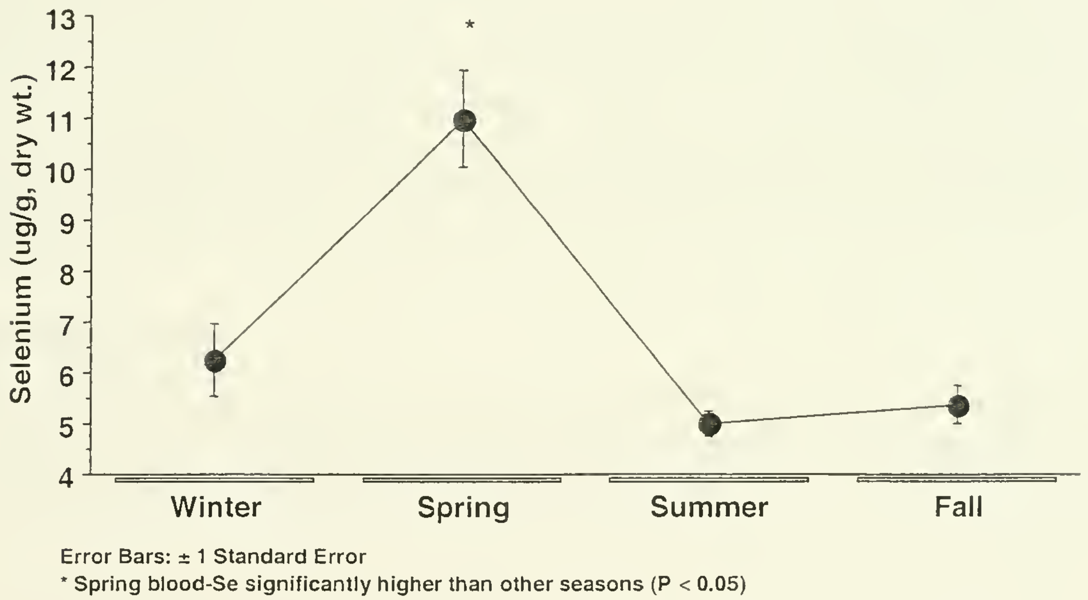


FIGURE 1-4
Seasonal Blood-Se Concentrations in Birds Sampled at Kesterson, 1994–2000

Within species sampled during the 2000 biological monitoring effort, comparisons showed that blood-Se was significantly higher in adult kestrels from Kesterson than those from the Kesterson Area (Kesterson = 7.7 μg/g, n = 5; Kesterson Area = 2.7 μg/g, n = 3). Adult loggerhead shrikes from Kesterson had higher blood-Se than adult shrikes from the

Sacramento Valley site (Kesterson = 8.7 μg/g, n = 2; Sacramento Valley = 3.9 μg/g, n = 6). When data for all species and years were combined, mean blood-Se in birds from Kesterson (5.8 μg/g) was significantly higher than in birds from the Kesterson Area (2.7 μg/g), Sacramento Valley (3.4 μg/g), Bay–Delta (2.5 μg/g), or Salton Sea (2.5 μg/g). Both individual and combined species blood-Se data are in agreement with current monitoring data from Kesterson showing consistently high levels of selenium in prey species and other biota.

Differences in blood-Se concentrations among species may be due to a number of factors. These factors probably include the relative time each species spent foraging within Kesterson, which is influenced by both season and home range characteristics; dietary exposure (various dietary items contain differing concentrations of selenium); and species-specific differences in selenium metabolism. Based on previously reported home ranges of these species and on observations at Kesterson, the highest blood-Se levels observed in loggerhead shrikes and the other passerines are probably due in large part to their small foraging ranges, making these birds spend more time foraging within Kesterson.

Nineteen kestrels, six barn owls, and five loggerhead shrikes were captured and resampled one or more times from one month to over two years after initial sampling. Sampling of retrapped birds did not show any trend of selenium accumulation. Of the 30 birds sampled two or more times, nine (6 kestrels, 2 barn owls, and 1 shrike) had increased blood-Se levels $\geq$ 1 μg/g, 13 (7 kestrels, 3 barn owls, and 3 shrikes) had decreased blood-Se levels $\leq$ 1 μg/g, and eight (6 kestrels, 1 barn owl, and 1 shrike) had no change in blood-Se levels when the final sampled blood-Se concentration was compared to the initial blood-Se concentration. Birds using Kesterson do not continually accumulate selenium but, depending on their movements and foraging ranges, are as likely to depurate selenium. It is likely that the barn owls and shrikes are resident (at least locally), based on the months that many were sampled, and also that many of the kestrels are also locally resident. However, this is a small sample size and it is not known conclusively which of these individuals are resident at Kesterson.

1.6 References

Yamamoto, J. T., G. M. Santolo, and B. W. Wilson. 1998. "Selenium accumulation in captive American kestrels (*Falco sparverius*) fed selenomethionine and naturally incorporated selenium." *Environmental Toxicology and Chemistry* 17:2494-2497.

SECTION 2

Wildlife Surveys

2.1 Introduction

In 1988, Kesterson was converted from a seasonal wetland that primarily supported a variety of waterfowl and shorebirds to an upland habitat that supports mainly terrestrial bird species. Since then, water-associated birds have not been an important part of the ecology. In only one year, 1998, did shorebirds (black-necked stilts and American avocets) nest at Kesterson. During most years, ephemeral rainwater pools do not last long enough to develop plant and invertebrate communities to attract shorebirds, thereby minimizing foraging on the site by these birds.

The number of birds changes based on yearly and seasonal changes of weather, food resources, and habitat changes. At Kesterson, the numbers of terrestrial species have also changed as the early successional habitat matured. The habitat at Kesterson is not actively managed. Without mowing, burning, or grazing, the saltgrass areas have become dense and choked with saltgrass thatch making nesting and foraging by grassland species difficult, and the number of ground-nesting grassland birds appears to be low. However, as the habitat develops and matures the number and size of the predominant shrub, perennial saltbush, have increased. These plants provide nesting and shelter habitat for species such as loggerhead shrikes and white-crowned sparrows.

2.2 Objectives

The objective of the wildlife surveys was to identify the species changes and general population trends found at Kesterson and to document these changes over time.

2.3 Methods

2.3.1 Daily Use Surveys

Monthly average populations for bird species such as shorebirds, swallows, blackbirds, and raptors were estimated from surveys that were used to calculate "daily use," which is also termed "use days." Daily use surveys are conducted by driving along the perimeter and interior access roads at Kesterson and recording the number and species of birds within each trisection. These surveys are conducted at least three days each month at various times of the day. For each month the total number of individuals of each species is divided by the number of days observations were made in the month to get an estimate of daily use by each species.

2.3.2 Transect Surveys

Estimation of bird use by upland species such as meadowlarks and sparrows was estimated by walking premarked transect belts (Dawson 1981). Transect surveys are particularly

suitable in extensive, open, uniform, or species-poor habitats (Bibby et al. 1992). To determine bird species occurrence and density, premarked belt (strip) transects were walked over a three-day period in the spring and again in the fall. To maximize counts, the timing of these surveys was determined by weather, as well as information taken from daily use bird surveys and other observations. Fixed transect belts (122 m wide, 61 m from the center) were laid out and staked in 1989 and have been maintained and used since then. By standardizing the observation area, observer variability is minimized. Transect length varied with Trisection (Trisection 1 transect is 2.72 km, Trisection 2 transect is 4.02 km, and Trisection 3 transect is 2.72 km) and was subdivided into 50-m intervals. All birds seen or heard within the transect belts were counted, identified, and recorded on preformatted data sheets that included date, time of starting and ending the survey, transect identification, species observed, and the number of individuals of each species observed. Observations either began at sunrise, ending three to four hours later, or began about four hours before sunset. The direction and order that transects were walked varied.

Data from the transect survey were used to calculate an estimate of density by the equation:

$$D = n/LW \qquad \textbf{Equation 2-1}$$

Where D = density, n = number of observations, L = transect length, and W = transect width (Emlen 1988). Simple percentages were used as indexes of relative abundance (Call 1982, Dawson 1981). Bird densities were converted to per-hectare bird densities and extrapolated to the entire Kesterson site to estimate monthly populations of species.

2.4 Results and Discussion

Common birds observed during the Daily Use surveys included killdeer, raptors (mostly northern harriers [*Circus cyaneus*], white-tailed kites [*Elanus leucurus*], red-tailed hawks, and American kestrels), swallows (mostly tree [*Petrochelidon pyrrhonota*], cliff [*Tachycineta bicolor*], and barn swallows [*Hirundo rustica*]), blackbirds (mostly Brewer's [*Euphagus cyanocephalus*] and red-winged blackbirds [*Agelaius phoeniceus*]), western meadowlarks, European starlings, loggerhead shrikes, and sparrows (mostly savannah [*Passerculus sandwichensis*], white-crowned, and song sparrows [*Melospiza melodia*]).

2.4.1 Shorebirds

Because the numbers of killdeer do not depend on presence of wetlands (unlike most of the other shorebird species that may occur at Kesterson) and their numbers in most years are so much greater than the number of other shorebird species at Kesterson, killdeer were separated from other shorebirds for this discussion.

Shorebird numbers were generally low at Kesterson in 2000 because there was little standing water. The only recent years with high shorebird use were 1992, 1993, and 1998 (Figure 2-1). Late rain in 1992 and 1993 caused ephemeral rainwater pools to form. Those pools attracted shorebirds (mostly black-necked stilts [*Himantopus mexicanus*] and greater yellowlegs [*Tringa melanoleuca*]) for foraging but these pools did not persist through the breeding season. In 1998, heavy rain caused pools at Kesterson and in the surrounding area to persist

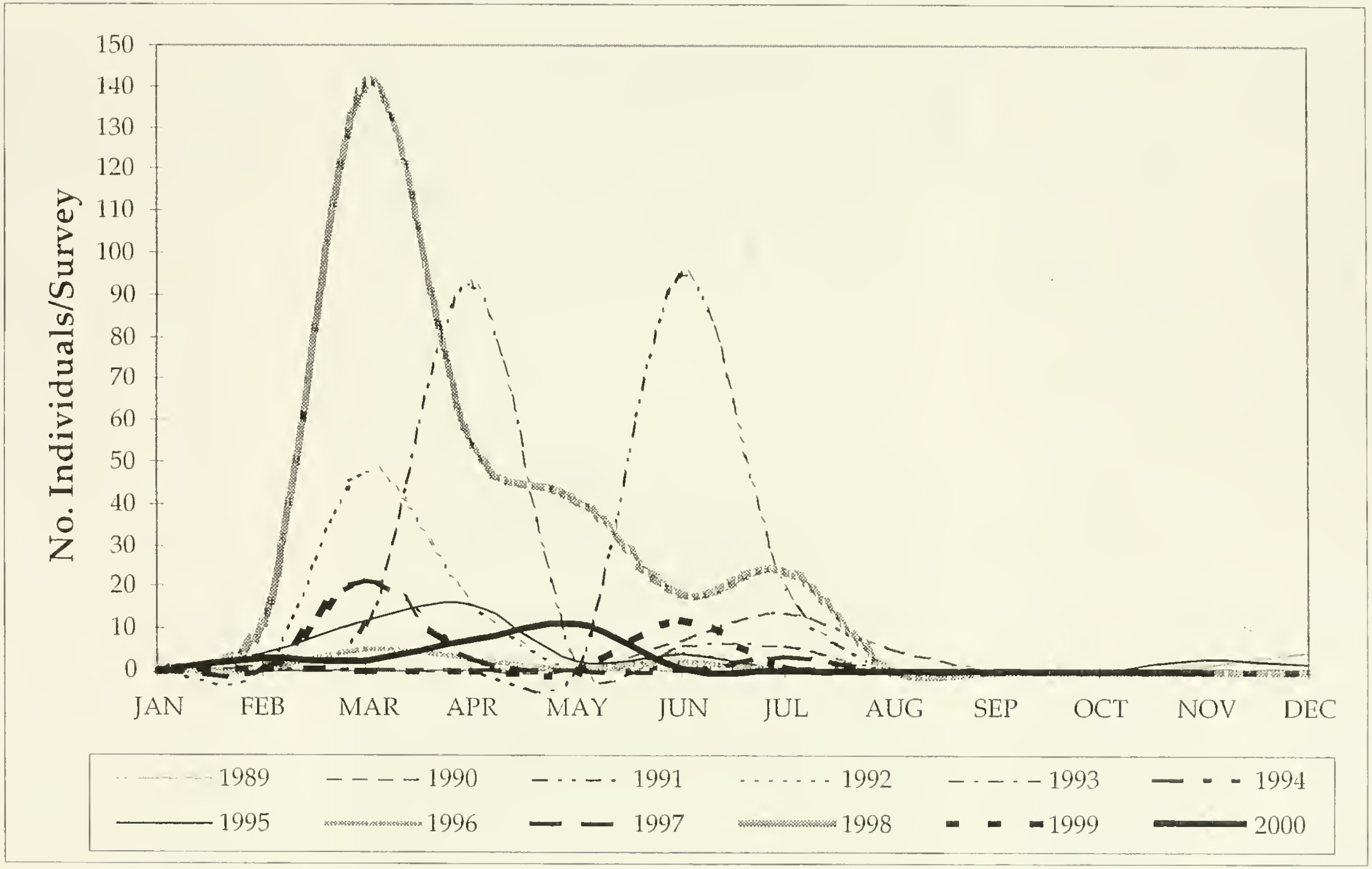


FIGURE 2-1
Shorebird (Other than Killdeer) Daily Use at Kesterson, 1989 – 2000.

into the breeding season (CH2M HILL 1998). During June 1991, large numbers of shorebirds were counted in the absence of ephemeral pools, but these were large flocks (up to about 100 individuals) of long-billed curlews that were observed foraging in open, grassy areas of Kesterson. The small increase in the number of shorebirds observed during May 2000 also was due to foraging long-billed curlews. No black-necked stilts or American avocets were observed at Kesterson during the breeding season.

In 2000, killdeer were seen in low average numbers at Kesterson, similar to the number of killdeer observed during 1999 (Figure 2-2). Two years stand out for killdeer at Kesterson: 1989, when there was little vegetation and shallow ephemeral pools covered large areas of bare soil during November in the year after filling of low areas; and 1998, when high rainfall caused flooding at Kesterson and much of the surrounding areas. During the reproductive period for killdeer (March through June), higher than normal nesting attempts were observed in 1998 (CH2M HILL 1998).

2.4.2 Raptors

General raptor numbers at Kesterson in 2000 were lower than during 1999 for most of the year (Figure 2-3). The number of raptors observed during the early fall of 2000 increased to numbers similar to those observed in 1999 and was higher than most other years. Raptor numbers generally follow the abundance of small prey, their primary food. For example, the number of red-tailed hawks and prey availability (based on trapping success) appeared to be related (Figure 2-4). Small mammal trapping success data indicate that the number of small mammals decreases over an approximate four-year span and then rebounds. Red-tailed hawk numbers and many other species follow the small mammal cycle (Figure 2-4) and wintering raptors probably respond primarily to prey availability. However, there are other limiting factors for raptors and other birds. American kestrel daily use only weakly followed small mammal trap success (Figure 2-5), but seemed to have strongly responded to the introduction of nest boxes to Kesterson. Kestrel numbers nearly doubled each year from 1995, when nest boxes were installed at Kesterson (1.4 kestrels per day), to 1999 (8.5 kestrels per day). 1999 had higher than average numbers of small mammals based on observations during monitoring, and this may account for the higher number of kestrels that year (CH2M HILL 2000). During the 2000 breeding season, small mammal numbers appeared lower than in 1999 and kestrel numbers were lower. The response of kestrels to adding nest boxes to the landscape suggests that kestrels were nest-site limited and Kesterson typically has resources to support five or six kestrel nesting pairs.

2.4.3 Blackbirds

Blackbird numbers typically increase during the fall and winter and decrease in the spring and summer (Figure 2-6). During the late fall and early winter of 1998 – 1999, blackbird use (primarily red-winged and Brewer's blackbirds) was higher than during other winters monitored, but 1999 – 2000 numbers were considerably lower. Relatively few blackbirds nest on Kesterson. The numbers of blackbirds using Kesterson seem to depend on their success and conditions in other areas. Kesterson may provide more upland areas for foraging during those winters when rainfall was higher than average and much of the surrounding area is flooded (CH2M HILL 1998). During spring 2000, blackbird numbers appeared to be above average.

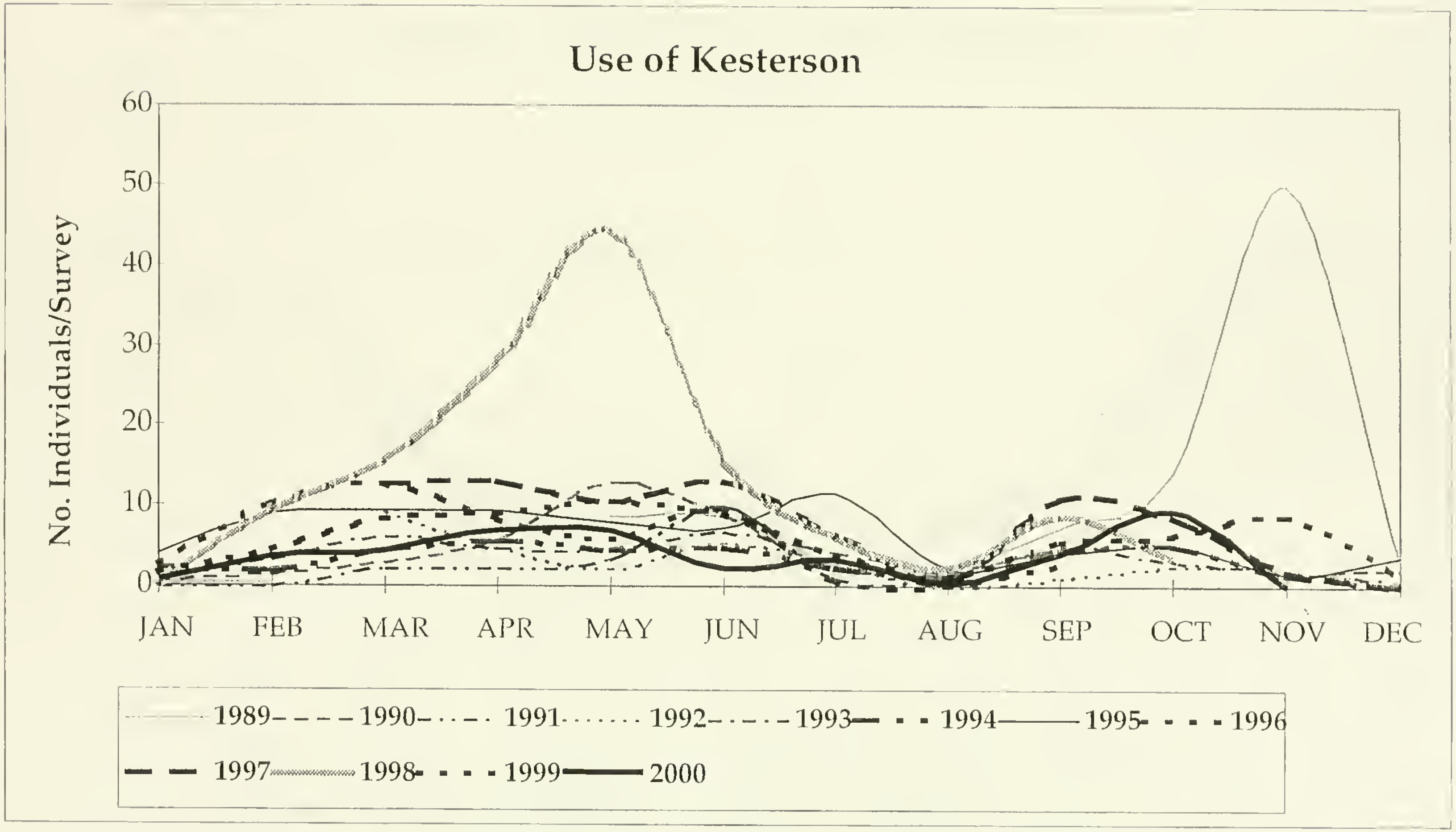


FIGURE 2-2
Killdeer Daily Use at Kesterson, 1989 – 2000.

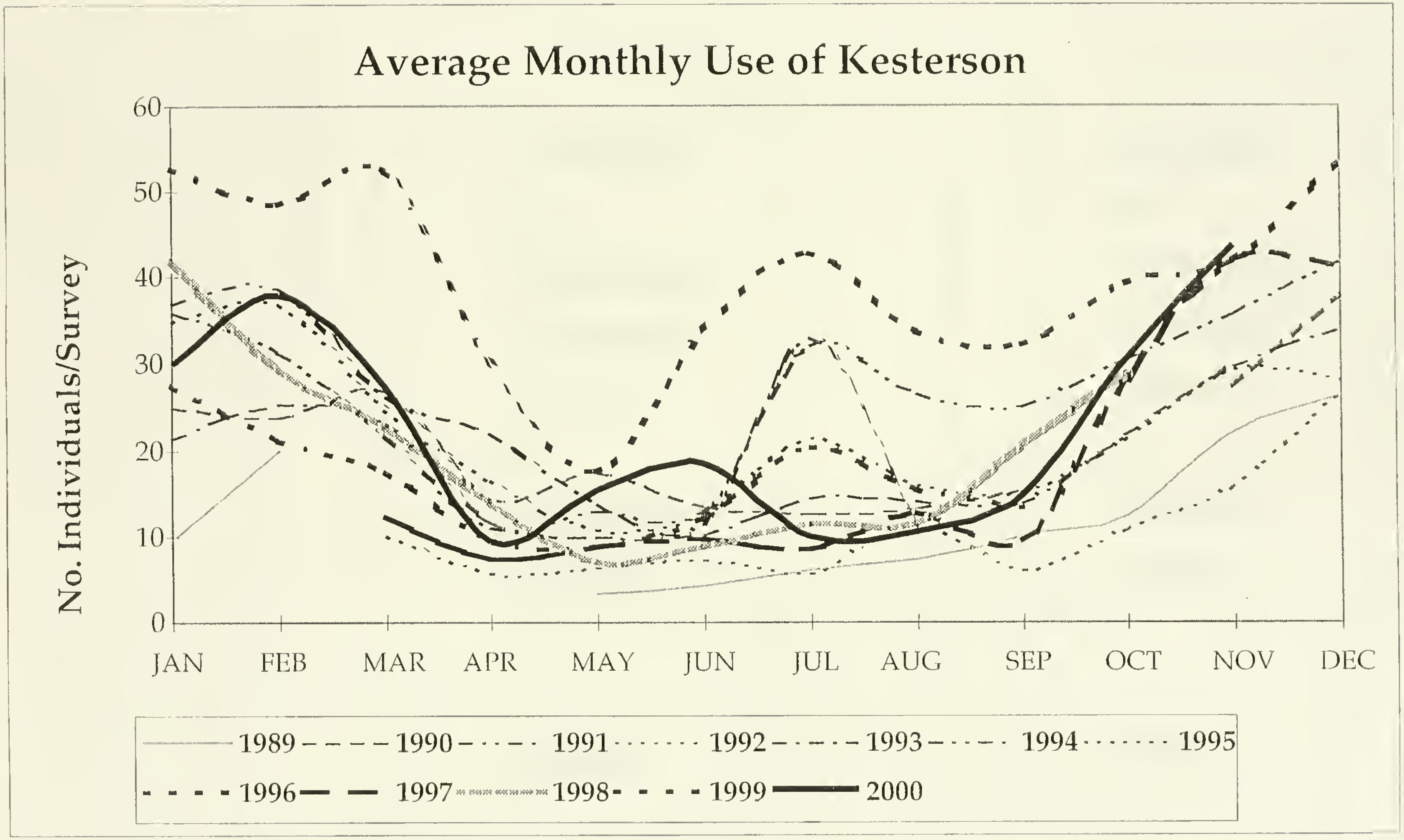


FIGURE 2-3
Raptor Daily Use at Kesterson, 1989 – 2000.

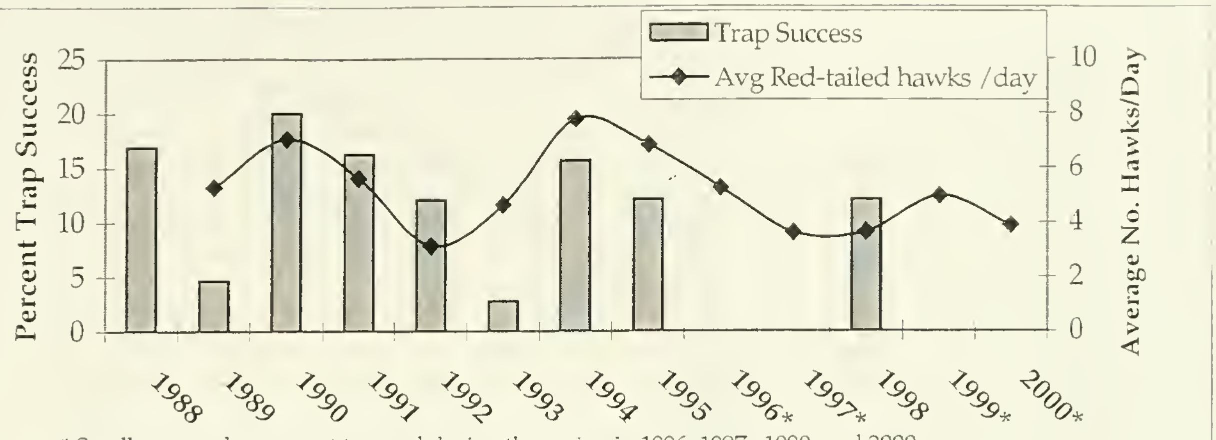


FIGURE 2-4
Red-tailed Hawk Annual Daily Average and Small Mammal Trap Success at Kesterson, 1989 – 2000.

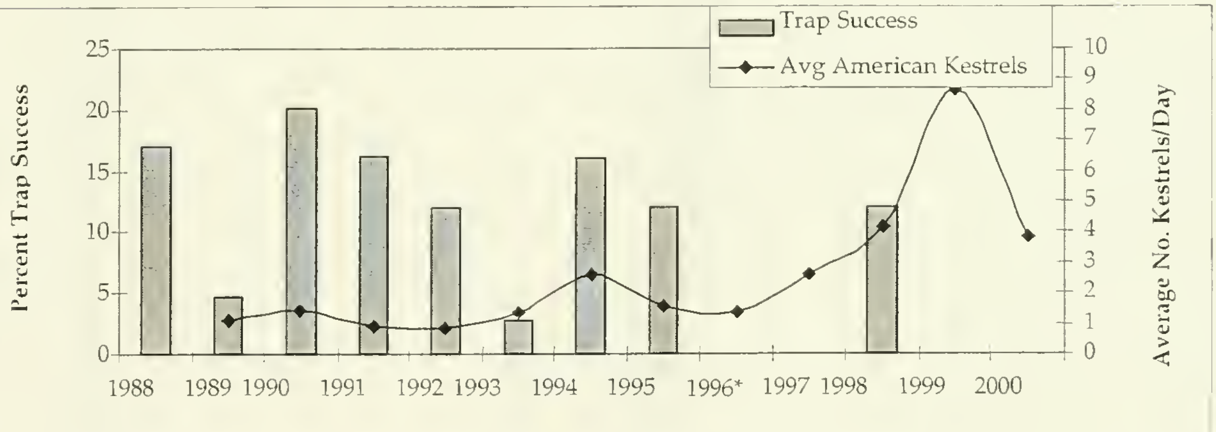


FIGURE 2-5
Average American Kestrel Daily Use at Kesterson and Small Mammal Trapping Success, 1989 – 2000.

2.4.4 Western Meadowlarks

Meadowlark daily use fluctuated during 1998–1999, but did not show consistent seasonal patterns during these years (Figure 2-7). In 1998, meadowlark numbers decreased from February to April, possibly because of the low availability of food items (invertebrates and seeds) due to flooding in large areas of Kesterson (CH2M HILL 1998). During 2000, meadowlark numbers remained relatively stable during the spring and summer and increased during the fall. Meadowlark nest searches were not conducted during 2000. However, in recent years, few meadowlarks have nested at Kesterson, although flocks of meadowlarks are typically observed foraging within Kesterson (CH2M HILL 2000). The more stable numbers may indicate that there was a nesting population at Kesterson during 2000.

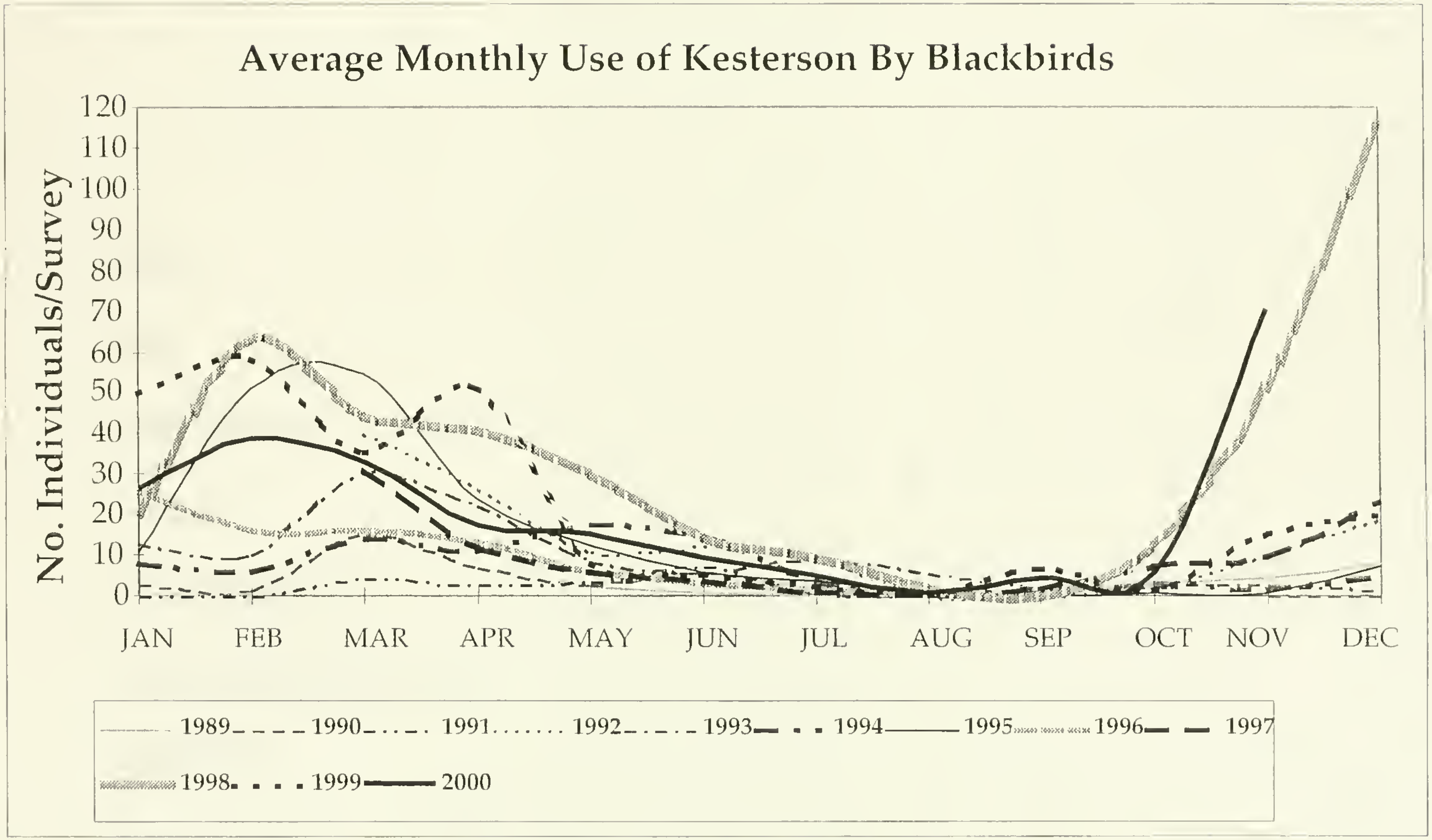


FIGURE2-6
Blackbird Daily Use at Kesterson, 1989 – 2000.

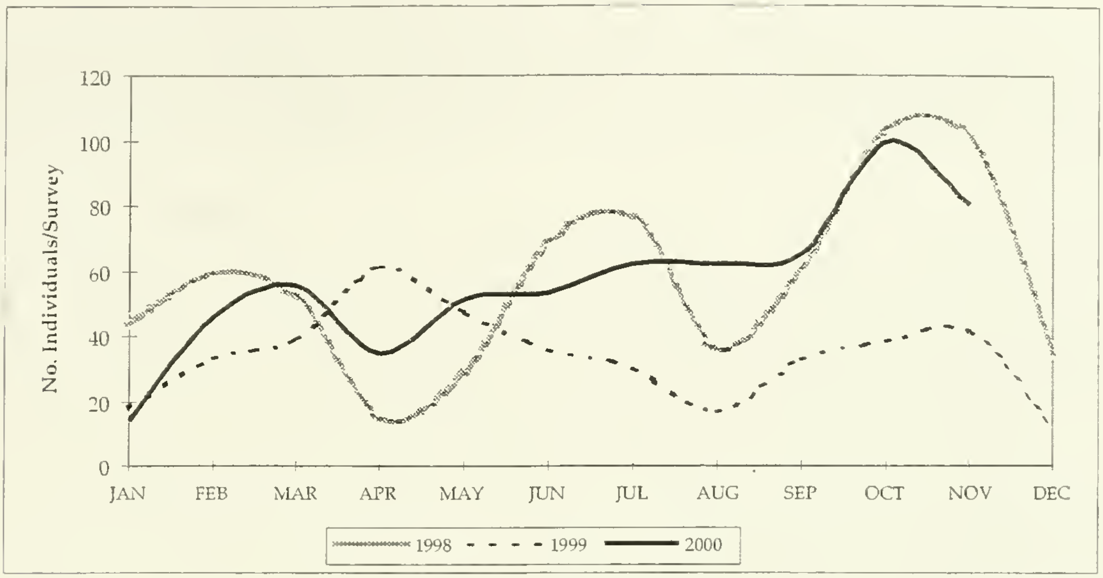


FIGURE 2-7
Western Meadowlark Daily Use at Kesterson, 1998 – 2000.

The number of meadowlarks observed each year probably fluctuates in response to factors such as food, weather, and habitat changes. During spring 2000 transect surveys produced lower numbers than those observed during spring 1999 but fall numbers were higher (Figure 2-8). Meadowlarks have been less abundant during spring in all years since 1989, the first year after low-lying wet areas were filled and vegetation was short and sparse. In contrast, meadowlarks have been more numerous during fall in all years since 1989. This difference is attributed to the lack of suitable habitat (short grasses for nesting and low-growing shrubs for perching) over much of Kesterson. The dense grasses and tall weeds found over most of Kesterson limit nest-sites for meadowlarks and other ground-nesting birds. The higher numbers observed during the fall are most likely due to an adequate

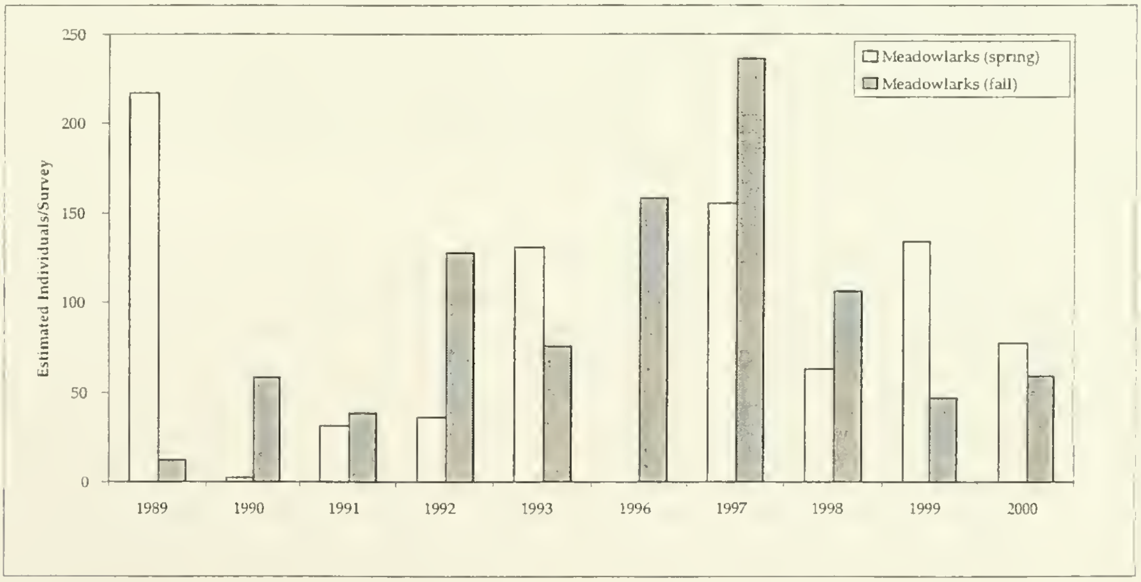


FIGURE 2-8
Spring and Fall Western Meadowlark Surveys, 1989 – 2000.

abundance of food and Kesterson's generally dryer condition compared to surrounding areas (including the duck clubs and wildlife refuge, which are generally flooded during much of the fall and winter months). Meadowlarks nesting in areas around Kesterson may tend to congregate and forage at Kesterson.

2.4.5 European Starlings

Although starlings were generally found in low numbers during all years monitored, there were some exceptions. Starling numbers were higher during the fall of 1998 and winter of 1999 than other times. As with other species, starlings probably utilized Kesterson more during the winter of 1998 – 1999 because of flooding in the surrounding areas. Increased use of Kesterson by starlings during some winters (Figure 2-9) may be due to flooding (either from high rainfall or management of duck clubs and wildlife refuges) of areas around Kesterson, causing starlings to concentrate in less flooded, upland areas. However, few starlings were observed during the winter of 2000. In spring, starlings are attracted to kestrel nest boxes, but they are removed from the nest boxes before they can successfully fledge young. Kesterson does not provide very good foraging habitat for starlings; they typically prefer urban and agricultural areas, where grasses are mowed or grazed (Cabe 1993).

2.4.6 Loggerhead Shrikes

Loggerhead shrikes are territorial and probably defend their territories at Kesterson throughout the year. The number of shrikes at Kesterson probably depends primarily on two factors: food availability and nest sites. Loggerhead shrikes feed on both small vertebrate and invertebrate prey. As has been discussed, food availability varies annually and some types of prey are cyclical. However, based on monitoring of arthropods and vertebrate wildlife at Kesterson, shrikes are probably not food-limited in most years and the availability of nest sites is probably an important limiting factor. Shrike nests found at Kesterson are in perennial saltbushes (*Atriplex*). Since the filling of low areas at Kesterson in 1988, there is more upland foraging habitat, the number of perennial saltbushes has increased, and shrike numbers appear to have also increased since then (Figure 2-10). Shrike numbers in 2000 were low to average compared to other years and, based on observations of shrike nests, nesting success was slightly lower than in 1997 and 1999. No shrikes were observed during Daily Use surveys conducted in June and July, although some individuals are known to have been at Kesterson during those months (i.e., shrikes were observed during other activities at Kesterson during those months).

2.4.7 Swallows

Four species of swallows (barn, cliff, tree, and occasionally violet-green swallows [*Tachycineta cuchrysea*]) were observed at Kesterson from 1989 – 2000. However, only barn swallows nest there each year. Barn swallow nesting is limited by the lack of available nest sites. Barn swallows use a vertical wall with an overhang to construct a mud cup-nest. At Kesterson, they usually use six culverts along Gun Club Road for nesting. Barn swallows and the other swallow species forage over the grasslands and ephemeral pools for flying insects. The number of swallows observed at Kesterson (Figure 2-11) has varied annually and seasonally, but those numbers have been relatively low in recent years with a few exceptions. During most of 2000, swallow numbers observed at Kesterson were low to average compared to other years. During the fall, tree swallows were the only species observed at Kesterson and numbers during fall 2000 were higher than other years.

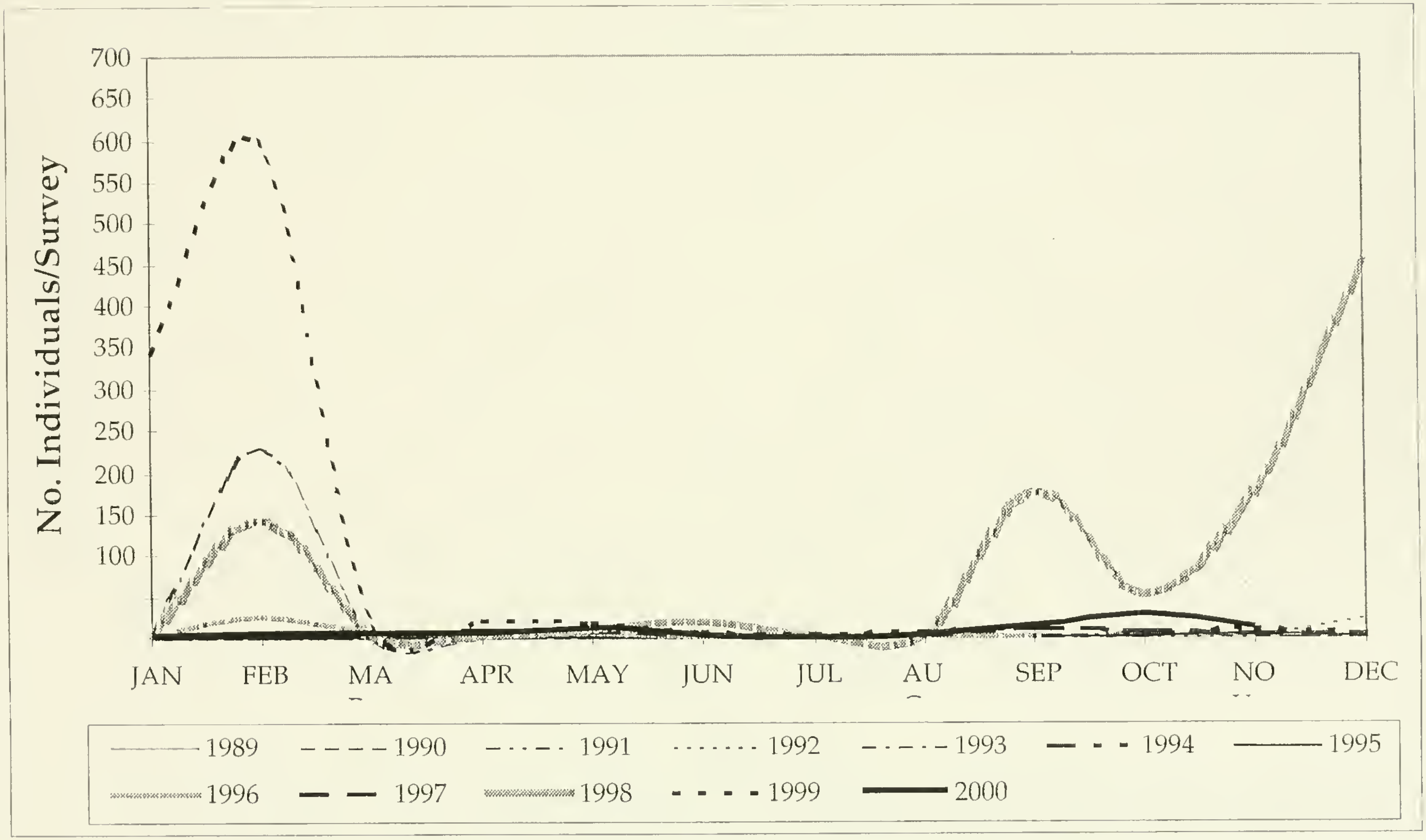


FIGURE 2-9
Eupropean Starling Daily Use at Kesterson, 1989 – 2000.

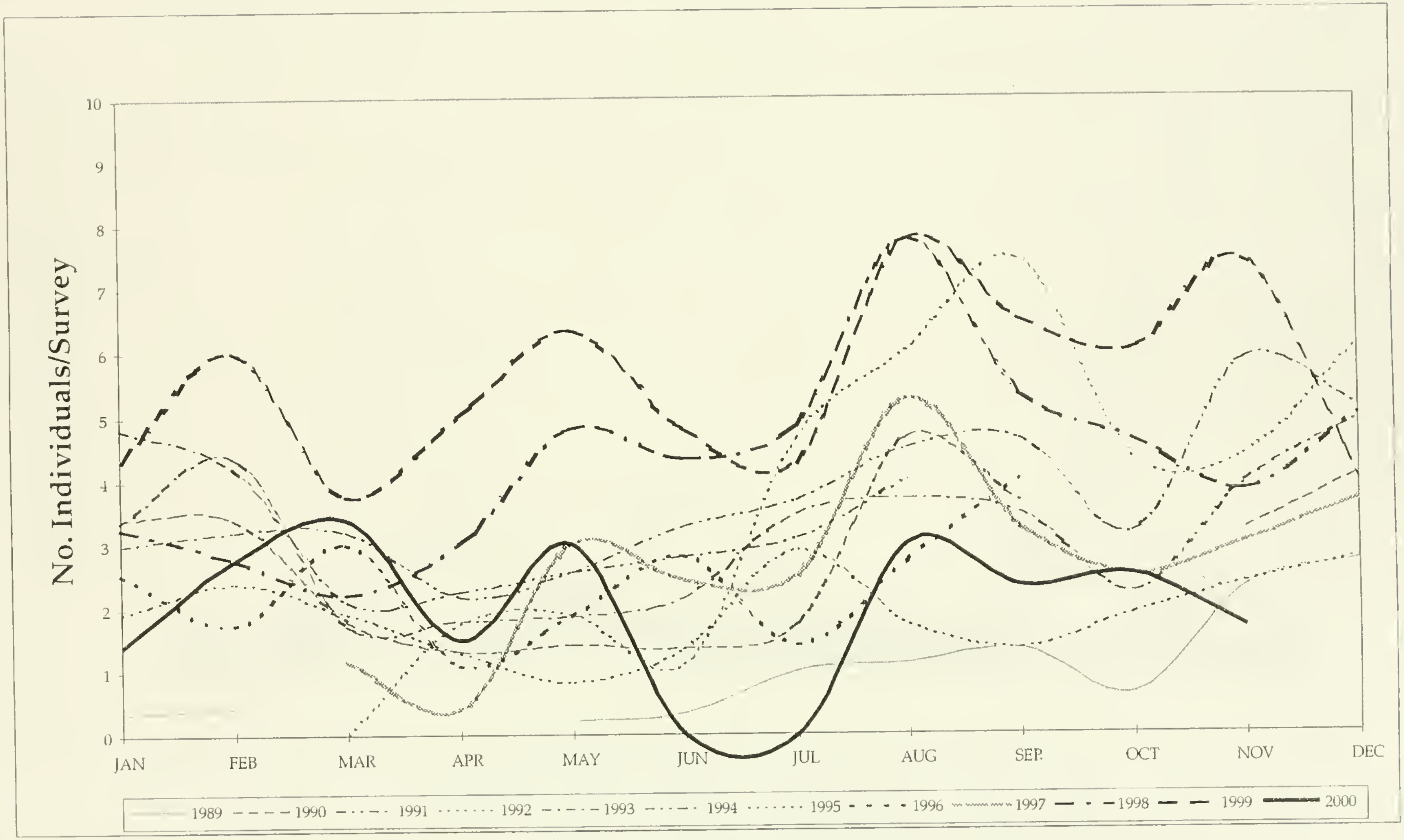


FIGURE 2-10
Loggerhead Shrike Daily Use at Kesterson, 1989 - 2000

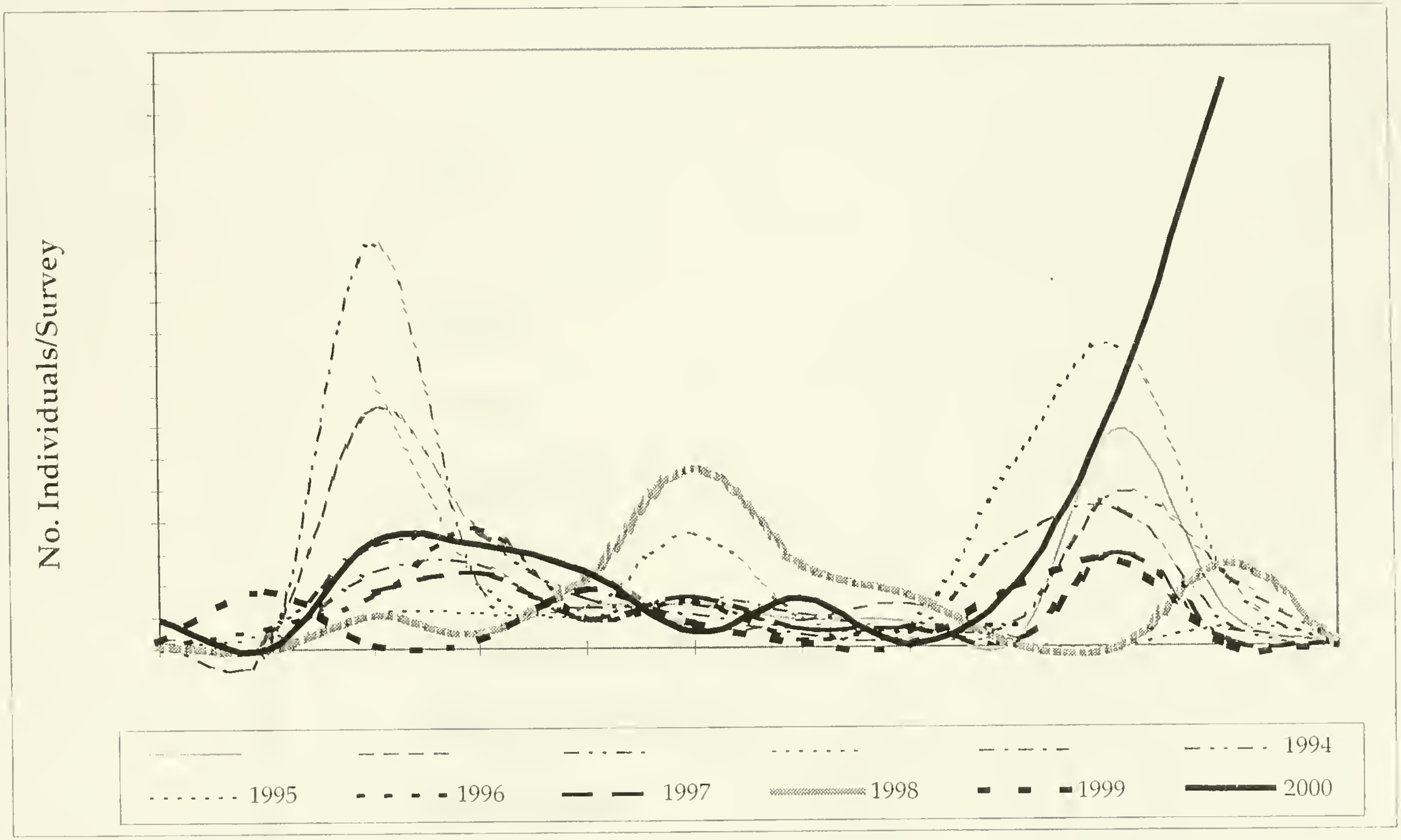


FIGURE 2-11
Swallow Daily Use at Kesterson, 1989 – 2000.

2.4.8 Sparrows

The most common sparrows observed at Kesterson are savannah, white-crowned, song, and grasshopper sparrows (*Ammodramus savannarum*). Since 1990, sparrows have been more common during the fall, and the numbers of sparrows during that season have generally increased. Also, the number of sparrows found at Kesterson during the spring has been increasing since 1996 (Figure 2-12). The increased sparrow use may be due to the presence of more and larger shrubs, especially perennial saltbush. Sparrows use these and other shrubs for shelter during the fall and spring. During the spring, the shrubs also are used as nesting sites. As the number of large shrubs has increased, shelter and nest site limitations have been reduced and populations of sparrows and other species have reflected this change. From 1997 to 1999, the number of sparrows observed during the fall has decreased and the number of sparrows observed during spring has increased (Figure 2-12). In 2000 the three-year trend ended and fewer sparrows were observed in the spring and more were observed in fall than in 1999 (Figure 2-12).

FIGURE 2-12
Spring and Fall Sparrow Observations at Kesterson, 1989 – 2000.

2.5 References

Bibby, C. J., N. D. Burgess, and D. A. Hill. 1992. *Bird Census Techniques.* Academic Press. San Diego, CA.

Cabe, P. R. 1993. "European Starling (*Sturnus vulgaris*)." *The Birds of North America,* No. 48. A. Poole and F. Gill, eds. The Academy of Natural Sciences, Philadelphia, and the American Ornithologists' Union, Washington, D.C.

Call, M. W. 1982. *Terrestrial wildlife inventories: some methods and concepts.* Bureau of Land Management Technical Note No. 39.

CH2M HILL. 1998. *Kesterson Reservoir 1998 Biological Monitoring Report.* Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region.

CH2M HILL. 2000. *Kesterson Reservoir 1999 Biological Monitoring Report.* Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region.

Dawson, D. G. 1981. "Counting birds for a relative measure (index) of density" *Estimating Numbers of Terrestrial Birds. Studies in Avian Biology No. 6.*

Emlen, J. T. 1988. "Estimating densities of birds derived from transect counts." *Auk* 88:323-342.

SECTION 3

Ephemeral Pool Monitoring

3.1 Introduction

Rainwater pools form at a number of locations in Kesterson Reservoir during the winter rainy season. Ponding has been observed in most winters and those pools surviving for greater than one month have been observed to develop populations of aquatic invertebrates. Selenium salts dissolve in the pools from the underlying soil and there is a concern that waterfowl or shorebirds feeding and nesting at Kesterson when ephemeral pools are present in the late winter/ early spring may accumulate significant amounts of selenium from their aquatic invertebrate prey in the pools.

Aquatic insect and crustacean species have been sampled from Kesterson ephemeral pools each winter since 1992, except for 1994 and 1999 when pools did not persist long enough to develop significant invertebrate populations. Annual monitoring of water and invertebrates in the most persistent ephemeral pools has been conducted as a means of tracking potential exposure of aquatic birds to selenium (mainly through their dietary items).

3.2 Methods

The current sampling year was a low-precipitation, limited-pooling year. Relatively few pools were sampled for the standard measurements of waterborne total selenium and aquatic invertebrate tissue selenium concentrations. Water samples were collected by hand as grab samples of raw water, with exceptions noted below. Invertebrates were collected with nets, sorted by taxonomic group in the field, and frozen prior to analysis for whole-body selenium content of composite samples.

A more intensive sampling effort was conducted at four pools to determine the partitioning of solubilized selenium in the pools and to elucidate the pathways of dissolved poolwater selenium to aquatic invertebrates. The water, the invertebrates, and their food sources were separately assessed for selenium concentrations. Aquatic invertebrates in the pools may be exposed to dietary selenium through water column detritus and plankton as well as the algae, fungi, and bacterial film that coats the substrates of the pool (the "aufwuchs" community). In addition, invertebrates are directly exposed to dissolved, water-borne selenium. Invertebrate dietary exposure was characterized by measuring the particulate, waterborne selenium fraction as well as the selenium content of algae and other micro-organisms inhabiting films that coat the pool substrates. The selenium concentration of the water column particulate food source was estimated by comparing concentrations in 0.45 μm pore size filtered water (which filters out essentially all detritus and algae) to aquarium net filtered (which filters out zooplankton, swimming insects, and debris) and raw water samples. Film-coating organisms were collected from acetate sheets that were left in the pools from March 6 to March 29, 2000 and had acquired a noticeable biotic coating. It is assumed that most of the colonizing biomass was from periphyton algae, as the coating was greenish-brown in color. Films obviously coated with suspended and redeposited sand

or mud were not used because they were considered an unreliable measure of the selenium content of the aufwuchs community.

3.3 Results

3.3.1 Extent of Pooling during the 1999 - 2000 Rainy Season

The limited ephemeral pool formation during the winter of 1999-2000 at Kesterson was similar to the 1998-1999 season but in marked contrast to the extensive pooling during the 1997-1998 season. Few pools formed during the 1999-2000 season, and those that formed did not persist for an extended period. February was relatively wet but conditions turned dry in March. All but two pools were dry by April (USBR 2000). Reclamation staff digitized aerial photographs taken on March 1, 2000 that show a total ephemeral pool area of 38 percent of the reservoir (21,171,464 ft^2) (USBR 2000).

3.3.2 Pool Water and Organism Selenium

Total selenium concentrations in the poolwater samples ranged from 1.93 to 247 $\mu g/L$ (Table 3-1). Selenium concentrations in Kesterson rainwater pools are dynamic over the lifetime of the pool. Samples typically show high selenium concentrations immediately after the pools form, and concentrations then fall to more stable values later in the season (Tokunaga, et al. 1994). The water monitoring data show this effect over the period of March 7 to 29 for several, but not all, of the pools shown in Table 3-1. Persistently high concentrations of selenium were found in Ponds 2 and 4. The main pool in Pond 11 (Pool 11-1) had the lowest selenium concentration.

The filtered pool water results indicate that most of the selenium in the pools is in dissolved form. Two pools showed no significant differences among filtered or unfiltered water, and in one case (Pool 1-2) filtered samples were actually slightly greater in concentration than those with various sized particles. In only one pool (Pool 5-2) were the filtered samples significantly lower in concentration (by about 3 $\mu g/L$) than those with particulate fractions, indicating a significant particulate selenium fraction. However, even in that case, the dissolved selenium was approximately 94% of the raw water concentration.

TABLE 3-1
Kesterson Ephemeral Pool Chemistry, 2000.
(Selenium concentrations in water by Hydride Generation AAS analysis, Lawrence Berkeley National Laboratory)

Pond/ Pool	Date	Raw Water Total Se (μg/L)	Aquarium Net-filtered Water Se (μg/L)	0.45 um mesh Filtered Water (μg/L)	Film-coating Biota (Aufwuchs) Selenium (μg/g DW)	Aquatic Invertebrates Collected	Aquatic Invertebrate Selenium Concentration (μg/g DW)
1/P1-1	3/7/00	23.7				*Daphnia*	52.3
						Corixids	28.2
						Beetles	35.1
1/P1-2	3/7/00	7.25				Notonectids	22.8
						Corixids	15.3

TABLE 3-1
Kesterson Ephemeral Pool Chemistry, 2000.
(Selenium concentrations in water by Hydride Generation AAS analysis, Lawrence Berkeley National Laboratory)

Pond/ Pool	Date	Raw Water Total Se (µg/L)	Aquarium Net-filtered Water Se (µg/L)	0.45 um mesh Filtered Water (µg/L)	Film-coating Biota (Aufwuchs) Selenium (µg/g DW)	Aquatic Invertebrates Collected	Aquatic Invertebrate Selenium Concentration (µg/g DW)
2/P2-ESE	3/7/00	247				*Daphnia*	177
2/P2-2	3/7/00	112				Corixids	20.2
3/P3-1	3/7/00	16.4				Notonectids	2.3
						Corixids	8.3
						Beetles	13.6
4/P4-1	3/7/00	80.6				Corixids	21
						Beetles	34.6
5/P5-2	3/7/00	62.1				Corixids	21.4
6/P6-1	3/7/00	15.9					
9/P9-1	3/7/00	133					
10/P10-1	3/7/00	137				Notonectids	23.8
						Corixids	16.7
						Beetles	149
11/P11-1	3/7/00	1.93				Notonectids	2.3
						Corixids	3.6
1/P1-1	3/29/00	22.5	22.8	23.1	11	*Daphnia*	35.3
	3/29/00	23.3	23.1	23.2		Beetles	26.7
	3/29/00	23.0	23.1	24.6			
1/P1-2	3/29/00	15.7	15.6	16.0*		Beetles	35.1
	3/29/00	15.7	15.5	16.5*			
	3/29/00	14.9	15.6	16.3*			
2/P2-ESE	3/29/00	126			190	*Daphnia*	177/124
4/P4-1	3/29/00	80.6			56		
5/P5-2	3/29/00	53.9	51.7	47.9**		Beetles	44.5
	3/29/00	50.9	53.6	48.6**			
	3/29/00	52.0	52.5	51.3**			
10/P10-1	3/29/00	63.2	63.2	66.6	21	*Daphnia*	76.4
	3/29/00	62.5	63.4	64.5		Beetles	149/92
	3/29/00	67.0	61.1	65.3			
11/P11-1	3/23/00				1.6		

* 0.45 µm mesh-filtered samples are significantly higher in concentration than raw or net-filtered values (ANOVA, $P < 0.05$)
** 0.45 µm mesh-filtered samples are significantly lower in concentration than raw or net-filtered values (ANOVA, $P < 0.05$).

3.4 Discussion

Few ephemeral pools were present at Kesterson Reservoir in 1999 – 2000. The few that were sampled had selenium concentrations similar to those observed in most years, although they were significantly lower in concentration for comparable pools and dates in 1999 (paired t-test, $P<0.05$) (CH2M HILL 2000a). The pools showed a general trend of decreasing selenium concentration from early to late March 2000.

The analysis of filtered water in the pools indicated that almost all selenium was in the dissolved fraction. The only exception was Pool 5-2, with approximately 6 percent of the waterborne selenium in particulate form. The net plankton component of the total selenium was not significant. Therefore, raw water measurements are generally indicative of poolwater selenium concentrations and little particulate selenium is available for invertebrate consumers.

Daphnia are water column, particle-feeding invertebrates. Unfortunately, pools with abundant *Daphnia* were too low in particulate selenium to allow a characterization of particulate concentrations (possibly due to *Daphnia* cropping). Assuming that Pool 5-2 represents a typical particulate selenium fraction (6%), the *Daphnia* in Pools 1-1, 2-ESE, and 10-1 may have consumed waterborne concentrations of approximately 1.4, 7.6, and 3.9 μg/L particulate selenium, respectively.

The attached periphyton and sediment surface probably affords the greatest availability of particulate, biologically-accumulated selenium for feeding by aquatic invertebrates. In fact, much of the small, waterborne particulate fraction may be resuspended matter from the pool bottom in this shallow, wind-exposed environment.

The aufwuchs community selenium content varied closely with pool water concentrations as does attached algae in laboratory experiments (Thomas et al. 1999). The highest concentrations were found in Pool 2-ESE, a pool with consistently elevated selenium concentrations. Ten-fold lower concentrations of selenium were found in the water and periphyton films of Pool 11-1. The growing aufwuchs and periphyton community accumulated selenium in direct correlation to the waterborne selenium concentrations (Kendall rank correlation, raw water vs. auwuchs selenium, $P< 0.05$).

Previous summaries have shown a significant positive relationship between aquatic invertebrate tissue selenium and waterborne selenium concentrations in Kesterson ephemeral pools (CH2M HILL 2000b). The year 2000 monitoring results show a similar pattern; the aufwuchs community as well as aquatic invertebrates show an increase in tissue selenium concentrations with increasing waterborne selenium concentrations (Figure 3-1). Note, however, that there are differences among taxa. *Daphnia* (cladoceran crustaceans), beetles, and the aufwuchs community show a generally log-log relationship with waterborne concentrations. In contrast, the concentration in hemipteran insects of the families Notonectidae and Corixidae increases until it reaches approximately 25 μg/g dry weight, and then appears to stop increasing with increased water concentrations (Figure 3-1). These results may reflect differences in selenium metabolism, dietary exposure, or both. Prey species for the notonectids (such as *Daphnia)* do not level off in concentration. Laboratory experiments have indicated that corixids fed selenium-contaminated periphyton algae will accumulate selenium from the food, but not from the surrounding water (Thomas

et al. 1999). Thus, it seems more likely that some aspect of selenium metabolism is affecting bioaccumulation in these hemipterans.

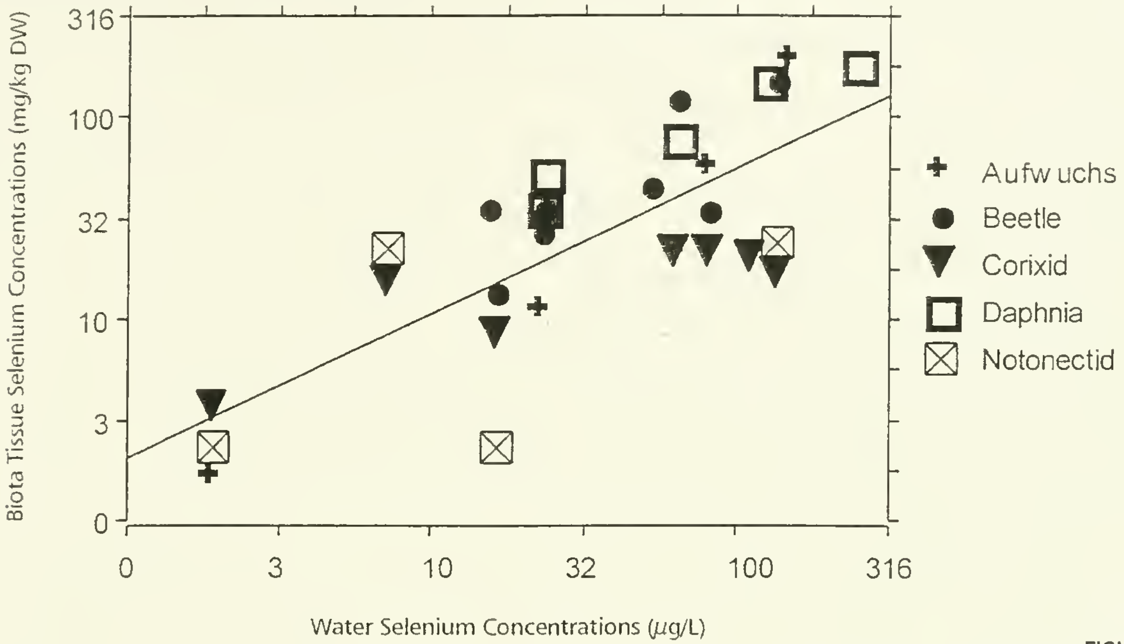


FIGURE 3-1
Ephemeral Pool Waterborne Selenium to Biota Relationship.
Significant log-log regressions ($P<0.05$)

The results indicate that both waterborne particles and attached surfaces provide potentially important pathways of selenium to the aquatic invertebrates. However, waterborne particulate concentrations are low. In contrast, the aufwuchs community accumulates selenium in direct relationship to poolwater selenium and appears on all surfaces where it is readily available as invertebrate food. In these shallow pools it is likely that periphyton and other aufwuchs organisms provide the primary dietary pathway of selenium in the pools to the aquatic invertebrates.

3.5 References

CH2M HILL. 2000a. *Kesterson Reservoir 1999 Biological Monitoring Report*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region by CH2M HILL, Sacramento, CA. April.

CH2M HILL. 2000b. *Ecological Risk Assessment for Kesterson Reservoir*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region by CH2M HILL, Sacramento, CA. December.

Thomas, B.V., A.W. Knight, and K. J. Maier. 1999. "Selenium bioaccumulation by the water boat man *Trichocorixia reticulata* (Guerin-Meueville)." *Arch. Environ. Contam. Toxicol.* 36:295-300.

Tokunaga, T.K., P.T. Zawislanski, P.W. Johannis, S. Benson, and D.S. Lipton. 1994. "Field Investigations of Selenium Specification, Transformation, and Transport in Soils from Kesterson Reservoir and Lahontan Valley." *Selenium in the Environment*. W.T. Frankenburger and S. Benson, Eds. Marcel Dekker, New York. Pp. 119-138.

U.S. Bureau of Reclamation (USBR). 2000. *Kesterson Reservoir Revised Monitoring and Reporting Program Semiannual Report.* April.

SECTION 4

Bird Nesting and Reproduction

4.1 Introduction

Nesting and reproduction of selected avian species using Kesterson were monitored during the spring of 2000 to determine the effects of selenium on these activities. In the past, reproductive effects of selenium have been observed in wild aquatic birds at Kesterson. These effects have included embryo mortality and teratogenesis, along with failure of adult birds to nest.(Ohlendorf et al., 1990; Skorupa and Ohlendorf, 1991). Kesterson was converted from a seasonal wetland to upland habitat in 1988, changing the primary species using Kesterson from water-associated species to terrestrial bird species. Monitoring of nests since 1988 has shown continued elevated selenium concentrations in eggs but no evidence of selenium-caused reproductive effects. Although elevated selenium is found in bird eggs and other wildlife, the selenium chemistry data generally indicate a low-level risk of avian reproductive effects. These low-level effects would be difficult to detect due to the generally small numbers of breeding birds present at Kesterson and have not been detected. Nest boxes were set up at Kesterson in 1995 partly to increase the number of nests for monitoring and data on starlings, kestrels, and barn owls have been collected since then. Monitoring birds that use nest boxes also allows sampling of parent birds, eggs, and young from the nest and conclusive determination of the fate of the nest. Egg selenium concentrations and success of birds nesting in the boxes is included here for comparison to other birds nesting at Kesterson. However, the results of the nest box studies are discussed in greater detail in the Predatory Bird Nesting Study.

Unlike 1998, when rainwater pools persisted throughout Kesterson, there was little rain during the reproductive season in 2000 and only a few, short-lived rainwater pools formed. Plant growth was normal and prey abundance was not measured. No black-necked stilts or American avocets were found nesting at Kesterson during 2000. This contrasted to 1998, when plant growth was delayed, terrestrial prey abundance was low, and stilts and avocets nested in higher numbers than in any year since the filling of low areas in 1988.

4.2 Objectives

The objectives of this study were to determine selenium concentrations in bird eggs and to assess the reproductive success of birds at Kesterson. Reproductive success was evaluated by determining the frequencies of embryonic mortality and developmental abnormalities, as well as hatching success of birds nesting during spring and summer of 2000.

4.3 Methods

4.3.1 Nest Searches

From mid-February through June 2000, biologists searched for nests of shorebirds, waterfowl, and terrestrial species at Kesterson and monitored them on a weekly basis. Most

killdeer nests were located by driving slowly along the levee roads and watching for the adult leaving the nest, displaying, or "sneaking" away from the nest. Other bird nests were located by looking for birds displaying behaviors associated with nesting activities, searching for adults on nests with binoculars, inspecting nest boxes, and opportunistically finding nests while conducting surveys and other activities.

4.3.2 Nest Monitoring

After a nest was found, it was marked with flagging approximately 10 ft away from the nest. The location was identified on a data sheet, and the nest was given a unique code. Nest codes include four-letter species acronyms, the pond number, and a nest number. Monitoring of the nest began immediately after its discovery and continued on a weekly basis to assess hatching success and nestling survival. Monitoring was conducted with minimum disturbance to the nesting birds. Each time the nest was visited, the date, nest code, and number and condition of eggs were recorded on data sheets. A nest was considered unsuccessful if all eggs failed to hatch. Nests were considered abandoned if a clutch was not completed or the nest appeared unattended on subsequent visits and eggs were cold. Predation of the nest was determined by disappearance of eggs from a nest before the expected hatching date or observation of partially eaten eggs or egg contents in the nest (Mayfield 1975, Ohlendorf et al. 1989).

4.3.3 Egg Collections

After a nest was located, one egg usually was removed if the nest contained two or more eggs. Eggs were not collected from some nests for various reasons; examples include some nests were found and the egg(s) lost to predators before they could be collected, or too few eggs were in the nest for collection (these nests appear in Table 4-1). Nests found after eggs hatched are also included in Table 4-1. All eggs from starling nests were collected, but only one egg usually was removed from other nests. At collection, each egg was marked with its unique nest code and the date it was removed. The data were recorded on a data sheet and the egg was placed in a container to avoid damage. Eggs removed from nests were either examined or refrigerated within 1 hour of collection.

4.3.4 Embryo Ages

Eggs were usually collected as soon as a nest was discovered to avoid losing samples to predation and to maximize the number of nests sampled for selenium. Embryos were considered viable if the egg was fertile or a living embryo could be observed (i.e., during breakout or candling). Most eggs contained embryos under 10 days old, before most abnormalities that are characteristic of selenium toxicity can be observed, and were classified as being normal and viable. However, embryo mortality is not distributed randomly during incubation of the egg. There are generally two embryo mortality peaks, one at about 2 to 3 days of development and a second, more pronounced mortality peak between 18 and 20 days of development. These peaks coincide with fundamental changes in physiological functioning of various parts and organs (Landauer 1967). Because most eggs were collected early during incubation, viability may be over-represented (i.e., eggs may have had early embryos that might have died in the later "mortality peak") for these samples.

4.3.5 Laboratory Examinations

Each of the eggs was opened as soon as possible after collection to determine its fertility, stage of development, the position of the embryo, and whether pipping had occurred (i.e., whether the embryo had begun to break out of the egg). Each embryo was examined for evidence of external deformities. The entire egg contents were then saved in chemically cleaned containers and frozen until shipment to the laboratory for selenium analysis.

4.3.6 Analysis of Risk

The clutchwise incidence of inviable eggs in a sampled killdeer clutch was calculated using the equation for black-necked stilts developed by Skorupa (1998):

$$Y = \exp(-2.327 + 0.0503X)/(1 + \exp(-2.327+0.0503X)) \qquad \text{Equation 4-1}$$

where: Y = Probability of ≥ 1 inviable egg(s) in a sampled clutch; and X = Selenium content of the random sample egg (μg/g, dry weight)

The preliminary indication is that killdeer may be less sensitive than stilts to embryonic selenium exposure (CH2M HILL 2000). Therefore, any error in assessing selenium risk for killdeer based on the stilt equation would probably tend to overestimate the error (i.e., on the side of safety; CH2M HILL 2000).

4.4 Results

The results of nest monitoring and egg collections from 2000 are presented in Table 4-1. Eggs that were not collected randomly (i.e., an unhatched egg from a clutch) are noted as "NR." These nonrandom eggs were not used in analyses of selenium trends but are provided for information and to determine whether failure to hatch may have been due to elevated selenium levels in the egg.

TABLE 4-1
Results of Nest Observations and Selenium Analysis of Eggs, Kesterson 2000

			Embryo[b]				
Species	Location[a]	Date Collected	Day[c]	Stage	# Eggs Clutch[d]	Egg-Se DW[e]	Fate of Nest
American kestrel	NB 01-03	16 APR 00	12	32	5	2.7	Successful
American kestrel	NB 05-01	16 APR 00	3	7	4	2.8	Successful
American kestrel	NB 09-02	07 MAY 00	26	45	5	3.5	Successful
American kestrel	NB 11-01	16 APR 00	9	28	5	2.7	Successful
American kestrel	NB 140-01	21 APR 00	16	36	5	2.0	Successful. Off-site nest.
Barn swallow	CUL 02-01	07 MAY 00	1	3	4	5.4	Successful
Barn swallow	CUL 04-01	07 MAY 00	2	6	4	4.1	Successful
Barn owl	BO 01-01	22 MAR 00	2	6	2	2.0	Successful

TABLE 4-1
Results of Nest Observations and Selenium Analysis of Eggs, Kesterson 2000

Species	Location[a]	Date Collected	Embryo[b] Day[c]	Embryo[b] Stage	# Eggs Clutch[d]	Egg-Se DW[e]	Fate of Nest
Barn owl	BO 03-01	02 APR 00	29	45	5	4.9	Successful
Barn owl	BO 04-01	02 APR 00	10	30	5	2.9	Successful
Barn owl	BO 11-01	16 APR 00	3	8	3	3.3	Unsuccessful
Barn owl	BO 11-01a	06 MAY 99			2 NR	4.1	Unsuccessful
Barn owl	BO 11-01b	06 MAY 99			2 NR	4.3	Unsuccessful
Barn owl	BO 12-01	16 APR 00	8	25	3	1.8	Unsuccessful
Brewer's blackbird	P 02-01	16 APR 00	1	3	1	11.7	
European starling	NB 01-01	07 JUN 00	2	7	3	8.5	All eggs collected
European starling	NB 07-01	05 MAY 00	10	40	6	7.4	All eggs collected
European starling	NB 08-01	05 MAY 00	12	43	6	6.6	All eggs collected
European starling	NB 09-01	16 APR 00		PD	6	2.5	All eggs collected
European starling	NB 10-02	05 MAY 00	12	43	5	3.1	All eggs collected
European starling	NB 12-04	06 MAY 00	10	40	5	3.1	All eggs collected
Killdeer	GC 01	19 MAR 00	1	3	4	5.0	Unsuccessful – predation
Killdeer	Cmp 01	18 JUN 00	14	36	4	2.2	Unsuccessful – predation
Killdeer	P 01-01	19 MAR 00			2	NC	Unsuccessful – predation
Killdeer	P 01-02	22 MAR 00			1	NC	Unsuccessful – predation
Killdeer	P 01-03	05 APR 00			1	NC	Unsuccessful – predation
Killdeer	P 01-04	09 APR 00	3	10	4	4.4	Unsuccessful – abandoned
Killdeer	P 01-05A	21 APR 00				NC	Unsuccessful – predation
Killdeer	P 01-05B	18 JUN 00	1	5	4	4.5	Unknown
Killdeer	P 01-06	24 APR 00			4	NC	Successful
Killdeer	P 02-01	04 JUN 00	9	30	4	2.2	Successful
Killdeer	P 02-02	04 JUN 00	2	7	2	6.9	Unknown
Killdeer	P 09-01	19 MAR 00			2	NC	Unsuccessful – predation
Killdeer	P 11-01	06 MAY 00	5	23	4	2.1	Successful

TABLE 4-1
Results of Nest Observations and Selenium Analysis of Eggs, Kesterson 2000

Species	Location[a]	Date Collected	Embryo[b] Day[c]	Embryo[b] Stage	# Eggs Clutch[d]	Egg-Se DW[e]	Fate of Nest
Killdeer	P11-03	24 MAY 00			2	NC	Unsuccessful – unknown
Killdeer	P12-01	26 MAR 00			3	NC	Unsuccessful – predation
Killdeer	P 12-02	06 MAY 00	2	8	4	1.6	Unsuccessful – eggs broken
Loggerhead shrike	L 01-01	16 APR 00	4	13	6	2.7	Successful
Loggerhead shrike	L 03-01	16 APR 00	3	8	5	3.0	Successful
Loggerhead shrike	L 04-01	02 APR 00	1	3	5	4.6	Successful
Loggerhead shrike	L 06-01	09 APR 00	1	3	6	2.7	Successful
Loggerhead shrike	L 07-01	02 APR 00	5	18	5	2.8	Predation
Loggerhead shrike	L 07-02	04 JUN 00	0	1	4	3.7	Predation
Loggerhead shrike	L 12-01	09 APR 00	6	32	5	1.6	Predation
Loggerhead shrike	L 165-01	13 MAY 00	1	2	5	2.1	Predation
Loggerhead shrike	L 165-02	04 JUN 00	1	3	2	2.5	Predation
Mallard	M 07-01	07 MAY 00				NC	Predation
Ring-necked pheasant	R 12-01	05 APR 00			6	0.49	Unsuccessful – predation
Western kingbird	W 165-01	21 MAY 00	3	8	4	4.4	Unsuccessful
Western kingbird	W 165-02	04 JUN 00	2	6	5	4.0	Unsuccessful

[a] A lowercase letter denotes an egg from the same clutch; a capital letter denotes a new clutch of eggs in the same location.
[b] Day and stage follow Hamburger and Hamilton (1951), Hamilton (1952), Hermes and Woodard (1987), and Pisenti et al. (1997).
[c] Days are days of incubation. Day 0 is < 1 day of incubation.
[d] NR = Nonrandom egg.
[e] NC = No egg collected.

4.4.1 American Kestrel

Four random eggs were collected from six nests located within Kesterson or along the San Luis Drain (Tables 4-1 and 4-2) and one egg was collected from a nest located near the entrance of the Kesterson Unit of the San Luis National Wildlife Refuge (SLNWR) north of Kesterson. Eighty-three percent of the kestrel nests at Kesterson were successful. The selenium concentration from eggs collected in 2000 was significantly lower than in eggs collected in 1999 and similar to concentrations in kestrel eggs from 1998 and 1997.

TABLE 4-2
Selenium Concentrations (μg/g dry weight) in American Kestrel Eggs Collected from Kesterson

Year	*n*	Range	Geometric Mean[a]	Comments
1997	3	3.1 – 4.0	3.6 A	
1998	7	2.3 – 5.0	3.4 A	Ephemeral pools late into the summer
1999	8	3.3 – 13	8.4 B	High prey abundance observed
2000	4	2.7 – 3.5	2.9 A	

[a] Geometric means sharing the same letters are not significantly different (n = 3, Tukey-Kramer HSD $P \leq 0.05$).

4.4.2 Barn Swallow

Two eggs were collected from two nests in 2000 (Tables 4-1 and 4-3). Nests are usually found in the culverts along the south side of Gun Club Road, and since 1991, five or fewer nests have been found each year. Both nests monitored were successful. Egg selenium concentration was in the low range for barn swallow eggs but similar to that of eggs collected in other years (Table 4-3).

TABLE 4-3
Selenium Concentrations (μg/g dry weight) in Barn Swallow Eggs Collected from Kesterson

Year	*n*	Range	Geometric Mean[a]	Comments
1988	33	3.8 - 11	6.6	Prior to dewatering and filling of Kesterson
1989	13	4.0 - 7.9	5.6	Kesterson dewatered in fall of 1988, many nest sites (culverts) removed.
1990	9	3.7 - 6.3	5.6	
1991	9	4.1 -6.8	5.2	
1992	3	4.2 - 6.1	4.8	
1993	4	5.1 - 5.6	5.3	Heavy March rain destroyed some nests
1994	5	5.4 - 11	7.5	
1995	1	5.3	-	
1996	1	7.4	-	
1997	2	4.2 - 8.5	6.0	
1998	3	6.0- 7.0	6.6	Ephemeral pools late into the summer
1999	5	4.3 – 7.2	5.6	
2000	2	4.1 – 5.4	4.7	

[a] There was no significant difference in Se concentrations among years.

4.4.3 Barn Owl

In 1996 a barn owl nest box was placed in the compound adjacent to Pond 4, and in 1997, barn owl nest boxes were placed in Ponds 1, 3, and 5. Two (wood duck) nest boxes were erected in 2000 (Ponds 11 and 12); barn owls were found nesting in each box except the one

in Pond 5, and an egg was collected from each (Table 4-1). During 2000, there were five nesting attempts and five random and two nonrandom eggs were collected (Tables 4-1 and 4-4). Eggs were collected from two nests that were later abandoned (BO 11-01 and BO 12-01). The five random barn owl eggs collected during 2000 had significantly lower selenium concentrations than those collected in 1999 but similar to 1998. Nest success for barn owls in 2000 was about 60 percent.

TABLE 4-4
Selenium Concentrations (μg/g dry weight) in Barn Owl Eggs Collected from Kesterson

Year	*n*	Range	Geometric Mean[a]	Comments
1997	1	8.0	8.0	
1998	6	2.4 – 6.7	3.4 B	Ephemeral pools late into the summer
1999	6	4.1 – 11	7.6 A	High prey abundance observed
2000	5	1.8 – 4.9	2.8 B	

[a] Geometric means sharing the same letters are not significantly different ($n = 3$, Tukey-Kramer HSD $P \leq 0.05$).

4.4.4 European Starling

We attempted to collect all starling eggs prior to hatching to increase nest box use by American kestrels and to limit reproduction by starlings (a non-native species). Starling nesting also was discouraged at Kesterson by removing nesting material from nest boxes when it was found, but, as in 1998, six clutches were laid in nest boxes and an egg from each clutch was analyzed for selenium (Table 4-5). One of the eggs examined had not developed an embryo although there was positive cell development (PD). Selenium concentrations in starling eggs collected in 2000 were similar to levels found in eggs from other years (Table 4-5).

TABLE 4-5
Selenium Concentrations (μg/g dry weight) in European Starling Eggs Collected from Kesterson

Year	*n*	Range	Geometric Mean[a]	Comments
1991	1	2.8	2.8	
1996	30	1.5 - 13	3.7	First year that nest boxes were available
1997	23	2.0 - 7.2	3.4	All eggs removed prior to hatching
1998	6	4.8 – 10	6.2	All eggs removed prior to hatching
1999	12	2.2 – 9.9	4.7	All eggs removed prior to hatching
2000	6	2.5 – 7.4	4.0	

[a] There was no significant difference in Se concentrations among years.

4.4.5 Killdeer

Eight killdeer eggs were collected from 16 nests that were found in Kesterson (Tables 4-1 and 4-6). Killdeer nests were found from March 19 through June 4, 2000: five nests were found in March, four nests were found in April, three nests were found in May, and four

were found in June. Three nests (19 percent) were found empty at the time the eggs were expected to hatch with no signs of predation and were assumed to have been successful. Eight nests (50 percent) were unsuccessful due to predation, one nest (6 percent) was abandoned, one nest (6 percent) was accidentally destroyed, and the fate of two nests and cause of failure of one nest were not determined (19 percent).

The geometric mean selenium concentration in killdeer eggs collected from Kesterson during 2000 was slightly lower than concentrations in killdeer eggs collected in most years since Kesterson was filled and dewatered (1989 through 1997 and 1999), and significantly lower than that of killdeer eggs collected in 1988 (before filling) and 1998 (Table 4-6).

TABLE 4-6
Selenium Concentrations (μg/g dry weight) in Killdeer Eggs Collected from Kesterson

Year	*N*	Range	Geometric Mean[a]	Comments
1988	24	6.5 - 58	15.8 A	Prior to dewatering of Kesterson
1989	9	3.5 - 15	6.4 BC	Kesterson dewatered in fall of 1988
1990	11	2.9 - 20	7.0 BC	
1991	7	3.1 - 12	5.4 BC	
1992	13	2.5 - 28	8.5 ABC	
1993	2	11 - 17	13.7	Heavy March rain interrupted nesting
1994	12	2.8 - 11	5.6 BC	
1995	12	2.3 - 13	5.7 BC	
1996	20	2.2 - 13	5.2 BC	
1997	29	1.8 - 64	5.2 BC	Interior and west-side nests found
1998	41	1.9 – 31	7.9 B	Ephemeral pools late into the summer
1999	12	1.9 – 10	4.1 BC	
2000	8	1.6 – 6.9	3.2 C	

[a] Geometric means sharing the same letters are not significantly different ($n = 3$, Tukey-Kramer HSD $P \leq 0.05$).

The expected clutchwise incidence of inviable eggs in a sampled clutch for killdeer was calculated as 10.5 percent (range = 9.6 to 12.1 percent). Background rate of clutches containing one or more inviable eggs was estimated as 8.9 percent (Skorupa 1998). Therefore, the statistical estimate is that 1.6 percent of clutches may have had selenium-induced impacts in 2000 without being detected. Thus, less than one egg out of the 8 nests from which a sample egg was collected (32 potential eggs) may have been inviable due to selenium.

4.4.6 Waterfowl

One mallard (*Anas platyrhynchos*) nest was found in Pond 7 at Kesterson in 2000, but the nest was unsuccessful due to apparent predation by a mammalian predator. All of the eggs had been broken and no sample egg could be collected for selenium analysis. In previous years

eggs from all species were combined as "duck" eggs for comparison. During the 1999 monitoring effort, two duck nests were found. Fewer waterfowl nests have been found at Kesterson since low-lying areas were filled in the fall of 1988. Few of the duck nests have been successful, with losses due to predation and abandonment despite relatively low selenium concentrations in most analyzed eggs. Selenium concentrations found in duck eggs have been similar over the years since filling in 1988 (Table 4-7).

TABLE 4-7
Selenium Concentrations (µg/g dry weight) in Duck Eggs Collected from Kesterson

Year	*n*	Range	Geometric Mean[a]	Comments
1988	15	3.9 - 31	12	Prior to dewatering of Kesterson
1989	1	3.7	3.7	Kesterson dewatered in fall of 1988
1990	2	1.7 - 3.1	2.3	
1992	1	1.1		
1993	4	1.9 - 15	5.8	Heavy March rain
1994	1	7.7	-	
1995	3	4.5 - 16	8.9	
1996	3	1.6 - 5.3	2.8	
1997	3	1.6 - 3.4	2.4	
1998	5	3.5 –11	5.7	Ephemeral pools late into the summer
1999	2	2.4 – 10	4.9	

[a] There was no significant difference in Se concentrations among years.

4.4.7 Loggerhead Shrike

Loggerhead shrike eggs were collected for the first time in 1998 when four nests were sampled at Kesterson. In 1999, five nests containing eggs were discovered in Kesterson, and one egg was collected from each nest. During 2000, nine eggs were collected from eleven nests found in or adjacent to Kesterson. Four of the nests monitored were successful and fledged young. Seven nests were apparently lost to predation. Selenium concentrations in eggs collected from nests on Kesterson in 2000 were significantly lower than in eggs from 1999 and similar to eggs collected during 1998 (Table 4-8).

TABLE 4-8
Selenium Concentrations (µg/g dry weight) in Loggerhead Shrike Eggs Collected from Kesterson

Year	*n*	Range	Geometric Mean[a]	Comments
1998	4	4.5 – 6.0	5.3 B	
1999	5	3.0 – 14	8.2 A	
2000	9	1.6 – 4.6	2.7 B	

[a] Geometric means sharing the same letters are not significantly different ($n = 3$, Tukey-Kramer HSD $P \leq 0.05$).

4.4.8 Other Nests

Other nests that were found at Kesterson in 2000 included ring-necked pheasant (*Phasianus colchicus*), western kingbird, and Brewer's blackbird. A single ring-necked pheasant nest was found in Pond 12 and an egg was collected (0.49 μg/g). The pheasant nest was lost to predators and was unsuccessful. Two western kingbird nests were found along the San Luis Drain south of Pond 1. Both had low selenium concentrations (geometric mean = 4.2 μg/g) and neither was successful, apparently due to predators. A Brewer's blackbird nest was found in Pond 2 and an egg was collected from the nest (11.7 μg/g). More blackbird nests occurred in Kesterson; however, these nests were not monitored for successful hatching and fledging. General observations indicate that many nests were lost to predation both at the egg and chick stage.

4.5 Discussion

Selenium concentrations in eggs varied within and among species collected from Kesterson in 2000 (Figure 4-1) but the geometric mean selenium concentrations were not significantly different between species. Black-necked stilts and American avocets that nested at Kesterson in 1998, a year with persistent rainwater pools onsite during the breeding season, did not nest at Kesterson in 2000, during which large rainwater pools did not persist through the breeding period. Of species with two or more eggs collected (and selenium results available), there was no significant difference in selenium concentration. This was probably due to variability in egg selenium (1.6 – 8.5 μg/g).

FIGURE 4-1
Selenium Concentrations (μg/g, dry wt) in Eggs of American Kestrels (AMKE), Barn Owls (BNOW), Barn Swallows (BRSW), European Starlings (EUST), Killdeer (KILL), and Loggerhead Shrikes (LOSH) Collected From Kesterson in 2000

Although selenium levels in many eggs were elevated above background levels, the concentrations found in eggs at Kesterson indicate a low-level risk of avian reproductive effects (i.e., probably ≤ 1 killdeer egg in 2000) and no seleno-toxic effects were observed in eggs collected during 2000. Given the small number of nests potentially affected, and the relatively high incidence of nest predation, it is not surprising that affected eggs and embryos were not found.

Of the eight killdeer eggs collected, none were inviable and no inviability was detected in monitored nests. At Kesterson, the overall detected rates of egg inviability in killdeer (the most frequently sampled species; 4.3 percent of nests containing at least one fail-to-hatch [FTH] egg) are somewhat lower than background (8.9 percent of black-necked stilt nests containing at least one FTH egg), as reported by Skorupa (1998). Since Kesterson was filled in 1988, the Kesterson Reservoir Biological Monitoring Program has found seven inviable eggs in the 225 nests located during the monitoring. In general, nests were monitored on a weekly basis after they were found and marked. However, eggs in many of those nests were lost to predation, desertion, or destruction of nests (e.g., road grading) before they hatched. From 1996 – 2000, over 56 percent of the nests were lost. Therefore, it was not possible to determine accurately the rate of egg inviability in killdeer. In 1998, when 21 killdeer and 16 black-necked stilt eggs were collected at Kesterson and incubated in the laboratory at UC Davis, there were no killdeer eggs in which embryos died before hatching and there were two stilt eggs in which embryos did not develop (12.5 percent). In addition, 41 eggs were collected for examination and selenium analysis, and no dead embryos were found in any of those eggs. Thus, it has not been possible to establish relationships between egg-selenium concentrations and reproductive impairment in killdeer, or to document the incidence of egg inviability (due to the high rates of eggs lost to predation, or perhaps other confounding factors).

Nest success for killdeer was lower than other years but similar to what was observed by other researchers. At Kesterson, the nest success for killdeer in which the fate was known was 32 percent in 1998, 47 percent in 1999, and 23 percent in 2000. In a study conducted in Colorado, nest success for killdeer ranged from 24-33 percent (Mabee and Estelle 2000), which is similar to nest success at Kesterson. Predation was the cause of failure in almost half (49 percent) of all the nests found in 1998 compared to 18 percent in 1999 and 50 percent in 2000 (in those for which the cause of failure was determined). Abandonment by the adults accounted for 14 percent during both 1998 and 1999 and only six percent during 2000 (Table 4-9).

TABLE 4-9
Fate of Nests Found at Kesterson, 2000

Species	Abandoned	Predation	Total Unsuccessful	Successful	Unknown	Total Nests
American kestrel	1		1	4		5
Barn owl	2		2	3		5
Barn swallow				2		2
Brewer's blackbird					1	1
Duck		1	1			1
Killdeer	1	8	10	3	3	16
Loggerhead shrike		5	5	4		9
Western kingbird		2	2			2
Ring-necked pheasant		1	1			1
Total nests	*4*	*17*	*22*	*16*	*4*	*42*

Random eggs were collected from almost every nest found. Eggs were collected early during the incubation period from most nests so as many nests as possible would be sampled (i.e., few nests were not sampled due to predation prior to collecting an egg). As in previous years, the goal was to provide an accurate representation of selenium concentrations for the entire site and help to determining possible "hot spots" or species at risk for identifying additional management strategies or sampling. Collecting early during the incubation period may increase the number of viable eggs reported (i.e., fertile eggs or those with living embryos) because there is potentially higher mortality later during incubation and embryo teratogenesis is more likely to be found in later-stage embryos. However, incubation of sibling eggs showed similar viability to nonincubated eggs from Kesterson (CH2M HILL 2000).

The number of killdeer nests found at Kesterson increased from 1993, when heavy rain early in the nesting season (for killdeer) interrupted nesting, to 1998. Nests were found in higher numbers in 1998 than in any other year they were monitored. In 1999 and 2000, fewer nests were found and fewer killdeer were observed at Kesterson (Figure 4-2). The timing of nest initiation was similar to most years. (It was later than in 1997, but earlier than in 1995, 1996, and 1999 [Figure 4-3]). Although onset of killdeer nesting seems to be partially determined by rainfall (Figure 4-4), only a few nests typically are started early and most nests are initiated by mid-May (Figure 4-3). The numbers of killdeer nests found were roughly proportional to the numbers of killdeer observed during the breeding season (about 2 killdeer for each nest; Figure 4-2), based on daily use surveys during the breeding period (February – June). However, in 1993, when there was heavy rain during the breeding season (March), there were about 8.5 killdeer observed for each nest. In 1998, the ratio was again 2.0 killdeer per nest and in 2000 the ratio was 1.6 killdeer for each nest found. The number of killdeer foraging and nesting at Kesterson generally increased during 1994 to 1997 and peaked in 1998 (Figure 4-2). However, the number of killdeer foraging on Kesterson during 1999 and 2000 was lower than that observed from 1995–1998. The lack of rainwater pools and the low nesting success by killdeer at Kesterson in recent years indicates that Kesterson may provide only marginal habitat for nesting killdeer.

Nesting conditions for the various bird species have changed and, in general, selenium concentrations in eggs have dereased since Kesterson was dewatered in 1988 (see Tables 4-2 through 4-8). Variations in climatic conditions (e.g., rainfall and temperature), the conversion of Kesterson from a wetland to a terrestrial ecosystem, successional changes in vegetation causing plant and animal species changes, structural changes in habitat, and disturbance during the reproductive season from monitoring and management activities are some of the factors that have contributed to these changes.

Foraging and nesting sites on Kesterson are limited for some species. Birds such as mallards and black-necked stilts are uncommon nesting birds at Kesterson because they now have less wetland habitat to attract them. Barn swallows that use concrete culverts for nesting are limited by the number of these structures left at Kesterson (many of these culverts were removed during filling of Kesterson). Killdeer, meadowlarks, nighthawks, and other ground-nesting species that prefer open areas around their nests may not find much of Kesterson suitable due to the tall weeds and grasses that grow there in most years. Conditions in 1999 and 2000 were more suitable for nesting by terrestrial birds, especially

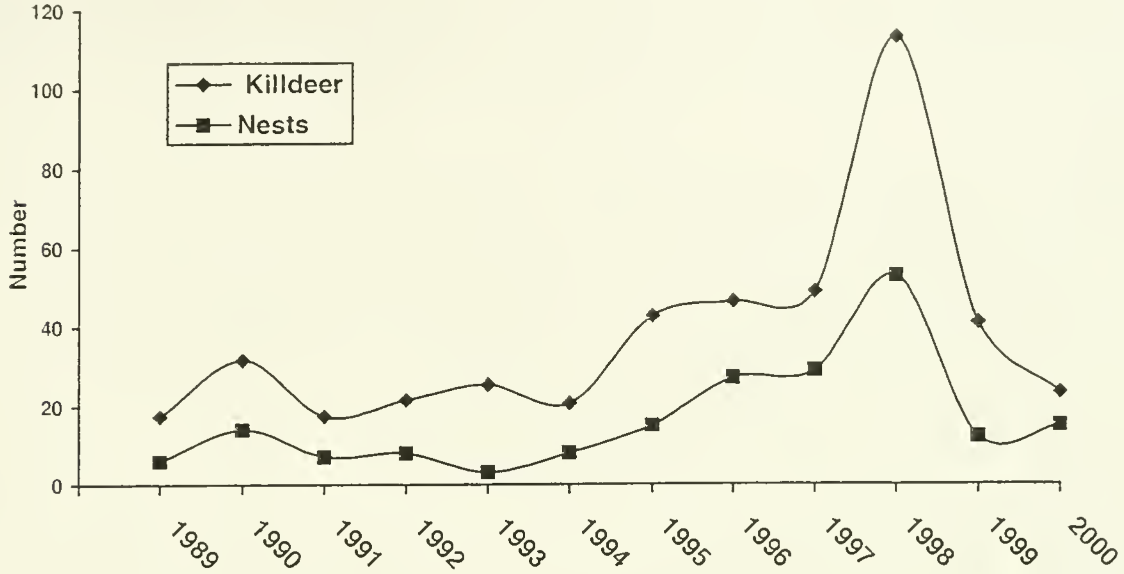


FIGURE 4-2
Number of Killdeer Observed (Daily Use) During the Breeding Season (February through June) and Number of Nests Found.

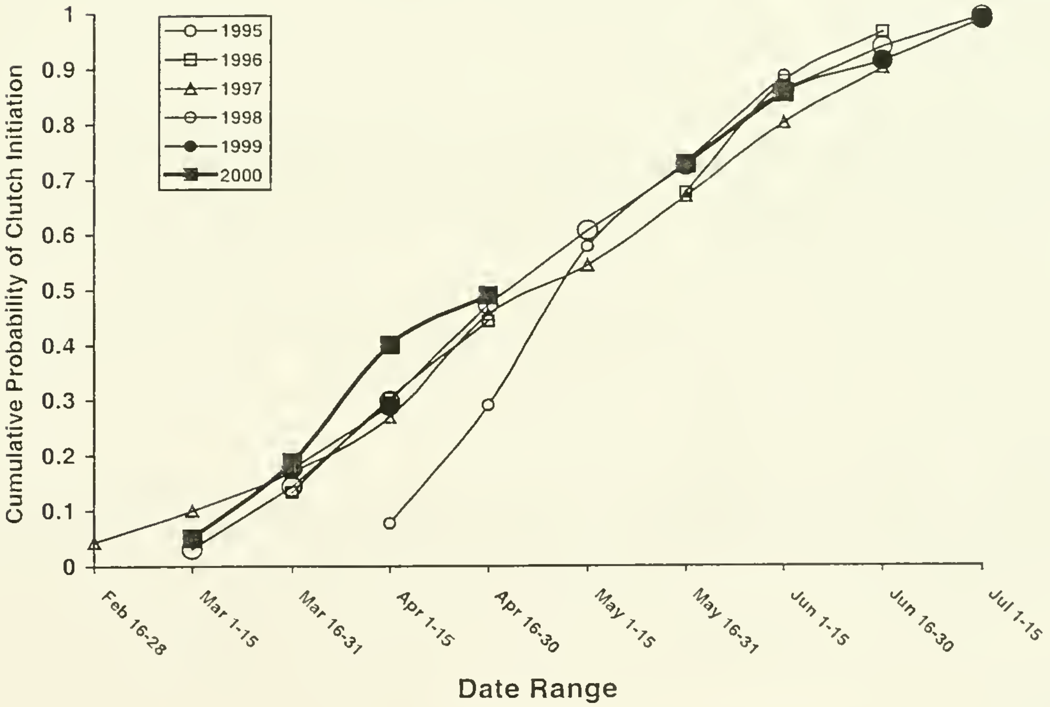


FIGURE 4-3
Cumulative Probability of Clutch Initiation by Killdeer

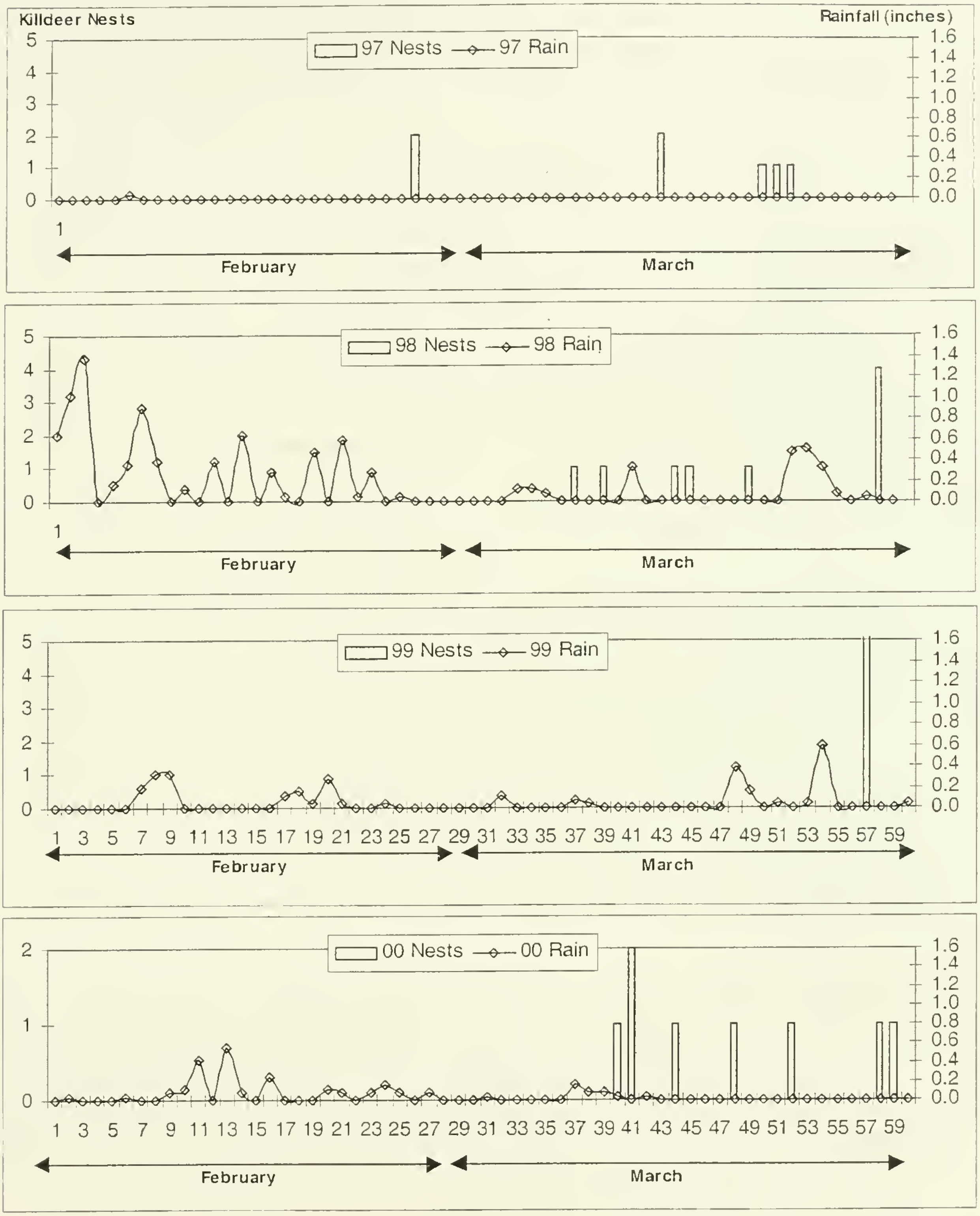


FIGURE 4-4
Rainfall (inches) and Killdeer Nests Started from February 1 Through March 30, 1997–2000.

avian predators, possibly due to the high number of small mammals observed late into the summer. Trapping for small mammals was not conducted for the KRBMP in 2000. However, based on small mammal sign observed and prey items in nest boxes, it appeared that prey was not a limiting factor.

Of the killdeer eggs collected at Kesterson (those eggs for which the fate could be determined), the percent of nests lost to predation (50 percent) was more than twice as high as the percent of successful nests (23 percent). The predation rate was higher than the 36 percent observed from 1984 – 1985 at Kesterson (Ohlendorf et al. 1989). With the possible exception of the blackbird eggs, none of the eggs collected in 2000 had concentrations above those expected to produce embryo toxicity and teratogenesis. Although hatching success was low, primarily due to predation, selenium-related effects in bird reproduction at Kesterson were not found. Many eggs continue to have selenium levels above median background levels of 1.9 $\mu g/g$, and 25 percent (2 of the 8 random eggs) collected from nests at Kesterson had selenium concentrations $\leq 5.0\ \mu g/g$, the maximum level for background selenium (NIWQP 1998) compared to 76 percent in 1998. None of the killdeer eggs were above the suggested avian threshold for reproductive impairment of 10 $\mu g/g$ (Heinz, 1996) compared to 16 percent of killdeer eggs in 1999 and 29 percent in 1998. None of the eggs collected in 2000 were above the threshold level for embryo teratogenesis for moderate taxa (e.g., black-necked stilt) (30 $\mu g/g$; NIWQP 1998).

In 1998, black-necked stilt and killdeer data were used to assess the potential for effects in embryo teratogenesis and egg viability. This analysis was not conducted in 2000 because no stilts nested at Kesterson and killdeer eggs collected were not incubated until late stages of development (evaluation of the late-stage embryo is used in the analysis). Typically, as observed from 1988 – 1997 and in 1999, stilts do not nest at Kesterson because it is maintained as upland habitat, so selenium risks to stilts do not exist in most years. However, killdeer are common nesting birds at Kesterson. Although this analysis was not repeated in 2000, the risk from selenium to killdeer nesting at Kesterson was likely lower than that in 1998. (That is, lower than the estimate of 2.2 to 3.4 percent probability of an eggwise incidence of inviability due to selenium exposure.) This is less than ten percent of the predation rate (50 percent) to killdeer nests at Kesterson and selenium is probably not a significant cause of mortality.

At Kesterson, barn owls nested in five of the six nest boxes available and appeared to be limited only by nest box availability. The one nest box not used is a different design (plastic instead of wood) and young were lost to predators at least twice in 1999. This nest box may not provide enough protection for barn owls and will be replaced. Fewer kestrels nested at Kesterson in 2000 than in 1999. That year seemed to be exceptional in terms of prey availability, and nest density for predators, such as barn owls, kestrels, and loggerhead shrikes, may have been above normal. Those that did nest in 2000 were generally successful and the reason for the lower density is not known. Non-Kesterson-related factors such as lower local population may be the cause of the lower nest density observed.

4.6 References

CH2M HILL. 1998. *Kesterson Reservoir 1998 Biological Monitoring Report*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

CH2M HILL. 2000. *Kesterson Reservoir 1999 Biological Monitoring Report*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

Hamburger, V., and H.L. Hamilton. 1951. "A series of normal stages in the development of the chick." *J. Morphol.* 88:49-92.

Hamilton, H. L. 1952. *Lillie's Development of the Chick.* Henry Holt and Co., Inc., New York.

Heinz, G.H. 1996. "Selenium in Birds." W.N. Beyer, G.H. Heinz, and A.W. Redmon-Norwood, eds. *Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations.* Lewis Publishers, New York, NY. Pp. 447-458.

Hermes, J. C., and A. E. Woodard. 1987. *Development of the Pheasant Embryo: A Record of Daily Visual Changes*. University of California, Department of Avian Sciences. 1m-pr-8/87-LE/ALS. Davis, CA.

Landauer, W. 1967. *The Hatchability of Chicken Eggs as Influenced by Environment and Heredity.* Monograph 1 (Revised). Storrs Agricultural Experiment Station, University of Connecticut, Storrs, CT. 315 pp.

Mabee, T. J. and V. B. Estelle. 2000. "Assessing the effectiveness of predator exclosures for plovers." *Wilson Bull.* 112:14-20.

Mayfield, H.F. 1975. "Suggestions for calculating nest success." *Wilson Bull.* 73:255-261.

National Irrigation Water Quality Program (NIWQP). 1998. *Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment.* USDI, National Irrigation Water Quality Program Information Report no. 3. 198 pp.

Ohlendorf, H.M., R.L. Hothem, and D. Welsh. 1989. "Nest success, cause-specific nest failure, and hatchability of aquatic birds at selenium-contaminated Kesterson Reservoir and a reference site." *Condor* 91: 787-796.

Ohlendorf, H.M., R.L. Hothem, C.M. Bunck, and K.C. Marois. 1990. "Bioaccumulation of selenium in birds at Kesterson Reservoir, California." *Arch. Environ. Contam. Toxicol.* 19:495-507.

Skorupa, J. P. 1998. "Risk Assessment for the Biota Database of the National Irrigation Water Quality Program." Prepared for the National Irrigation Water Quality Program. Washington D.C.

Skorupa, J. P., and H. M. Ohlendorf. 1991. "Contaminants in drainage water and avian risk thresholds." *The Economics and Management of Drainage in Agriculture.* A. E. Dinar and D. Zilberman, Eds., Kluwer Academic Publishers. Boston, MA. Pp. 345-368.

SECTION 5

Predatory Bird Nesting

5.1 Introduction

Elevated dietary selenium is known to cause embryo mortality and teratogenesis in some avian species. These effects have been studied at Kesterson in the past. Adverse reproductive effects in terrestrial birds have not been observed in the course of avian monitoring at Kesterson since it was dewatered and filled in 1988. To better study selenium exposure patterns of terrestrial birds, artificial nest boxes were placed in and around Kesterson during the late winter-early spring period in 1995 to attract American kestrels, a target monitoring species at Kesterson. Under these circumstances individual birds and their nests can be monitored closely to provide site-specific information on exposure to, and the effects of, high dietary selenium concentrations. In 1997 and 1998, data on selenium tissue concentrations, diet, reproductive success, and foraging range were collected at Kesterson and at off-site nest boxes. In 1996, European starlings also occupied the nest-boxes and were sampled extensively for selenium in tissues and for dietary composition analysis (see CH2M HILL 1996). Nest-box studies have been used by others (e.g., Grue and Christian 1981, Craft and Craft 1996) to study effects of contaminants on avian reproductive success.

In addition to the kestrel/starling nest boxes, six barn owl nest boxes were placed in the ponds at Kesterson during 1996-2000. Selenium residue and reproductive success data have been collected on nesting owls since 1996. Barn owls are common all year at Kesterson, and are capable of breeding year-round when conditions permit (CH2M HILL 2000, Marti 1992).

Loggerhead shrikes are also predatory birds that nest at Kesterson and have been studied since 1998. Although they do not use nest boxes but build cup nests in shrubs and trees, they are similar to kestrels and barn owls in their behavior, nest site fidelity, and habituation to nest disturbance. For the Kesterson Reservoir Biological Monitoring Program, they have the advantage that their home range is relatively small and should reflect the dietary selenium concentration around their nest sites to a greater degree than species with larger ranges.

In 2000, nest box and shrike studies were continued. Data for barn owls, kestrels, and shrikes are described in this section; starling data are reported in the section on Bird Nesting and Reproduction.

5.2 Objectives

The objective of this study was to determine reproductive effects of selenium on predatory birds at Kesterson. A secondary objective was to compare and follow selenium concentrations through the food chain to eggs and young of nesting birds at Kesterson

5.3 Methods

5.3.1 Setting Up the Nest Boxes

On February 7 through 9, 1996, 30 kestrel nest boxes were set up on Kesterson. They were placed in lines running east-west, approximately 1/4 mile apart (Figure 5–1). Eleven of the boxes were fastened to existing power poles within Kesterson (eight nest boxes were located along the San Luis Drain and three along Gun Club Road) and 19 were fastened to 12-ft pressure-treated 4-by-4s sunk about 3 feet into the ground. At each of these locations the posts were placed on the highest point in the area to gain additional elevation. Each box was lined with at least 3 inches of wood shavings. Each box was given a unique code. Codes identified type of nest (NB), where the box was located (Pond 1 through 12 or State Route 140 or 165) and a series beginning with the number 1 for each pond. For example NB 01–01 identifies a nest box in the northeast corner of Pond 1 and NB 01–04 identifies a nest box in the southwest corner of Pond 1. Aluminum tags with the number were attached to each nest pole and the location and number were identified on a map.

On March 1, 1996, one more box was fastened to an existing pole in the northwest corner of Pond 4 (Trisection 1). Five boxes were also installed outside Kesterson: two along Highway 140 by the main entrance to Kesterson National Wildlife Refuge (KNWR), and three on Highway 165 from the east gate of KNWR (i.e., the intersection of Highway 165 and the San Luis Drain) south. Four of these were mounted on existing poles and one was attached to a eucalyptus tree. In 1998, two nest boxes were removed and the total number of nest boxes available in 2000 was 29.

The nest boxes were made of redwood, about 1-1/2 ft tall, 1 ft deep, and 1 ft wide. The lids were either hinged or totally removable with hook and eye clasps to lock them on. Boxes were ventilated through the entrance hole and through holes drilled in the bottom. Prior to the 1997–2000 nesting seasons, nest boxes were inspected for damage, cleaned out and refilled with pine shavings.

Barn owl boxes were set up in 1996 (compound adjacent to Pond 4), 1999 (Ponds 3 and 5), and early 1998 (Pond 1). Nest boxes were made of wood or plastic, with varying construction designs, and were hung on 4 × 4 posts or already available structures at heights of 6 to 8 ft above the ground. Two additional nest boxes were set up in 2000 (one in Pond 11 and one in Pond 12).

5.3.2 Nest Box Monitoring

Pairs of kestrels and loggerhead shrikes were observed for signs of nesting beginning in March 2000. Barn owl nest box monitoring, which began in March 2000, continued through September 2000. Established kestrel pairs were identified by observations of birds entering and leaving nest-boxes, nest territory defense behavior, and food deliveries by the male to the female at the box. Barn owl nests were identified primarily by observation of eggs in the nest boxes. Nest boxes were checked several times during the year: during egg-laying or early incubation, when one egg was collected for viability assessment and selenium analysis; during chick rearing, when chicks were assessed for overall health/normality, banded (Federal bands), and blood-sampled; and post-fledging, when fledging success was determined (absence of chicks at the appropriate time was assumed to indicate successful

147841.00.RP nest_locs.FH8 01-05-01 dash

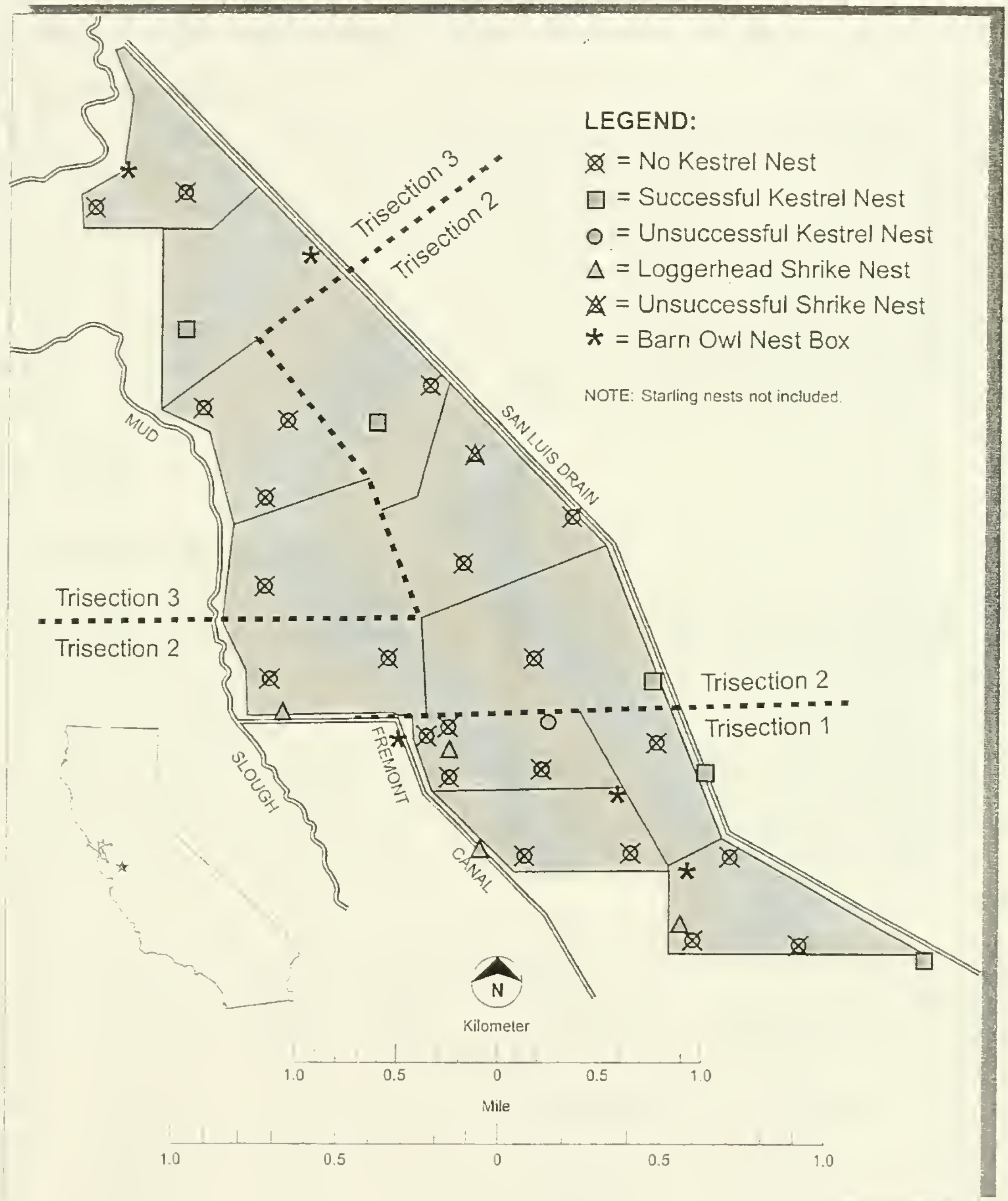


Figure 5-1
Approximate Locations and Fate of Nest Boxes on Kesterson Reservoir

CH2MHILL

fledging). Capture of the adult female in the nest box was attempted during early incubation, after egg-laying was complete; females were blood-sampled, banded (Federal bands), and placed back in the nest box within approximately 30 minutes of capture. Nest boxes that were apparently occupied by kestrels, but then abandoned, were also checked to assess stage of reproduction at which abandonment occurred and fate of the adult kestrels.

5.3.2.1 Radiotelemetry Data

Telemetry studies were conducted during the 1997 nesting season and ended after the 1998 nesting season. The results were used to determine the foraging ranges used by kestrels (CH2M HILL 1998). The amount of time foraging on and off Kesterson varies depending on factors such as nest location within Kesterson, food availability, habitats and physical differences, and the location of conspecifics. Breeding male kestrels from four nest boxes in 1997 (Ponds 1, 4, 8, and off-site box 165-01) and three in 1998 (Ponds 1, 4, and 12) were successfully radiotagged (CH2M HILL 1998) and their foraging activity was tracked. Based on analysis of telemetry data from these breeding male kestrels, male kestrels spent about 56 percent of the time through the breeding season foraging on Kesterson.

5.4 Results

5.4.1 Reproductive Success

Table 5-1 presents reproductive results for the past three years for shrikes, kestrels and barn owls. Success varied from year to year, but the percent of successful nests was greater than 50 percent in all species and all years, except for shrikes in 1998. No developmental abnormalities were observed.

Six of the 29 kestrel nest boxes were occupied (20 percent occupancy) and five nests successfully fledged young in 2000 (83 percent nest success). One of the six nests failed after one egg had been laid. Two offsite nest boxes were used and one was successful. No developmental abnormalities were observed in embryos in eggs that were examined.

TABLE 5-1
Reproduction in Kestrels and Barn Owls Using Nest Boxes On and Off Kesterson Reservoir, 1998 – 2000.

Species	Nest Location	Number of Nests[a]	Mean Clutch Size	% Incubated Eggs Hatched	% Developmental Abnormalities	% Successful[b] Nests
1998						
Shrike	Kesterson	4	4.3	59	0	25
Shrike	Off-site	2	–[c]	–[c]	–[c]	100
Kestrel	Kesterson	6	4.6	100	0	67
Kestrel	Off-site	2	6	100	0	50
Barn owl	Kesterson	4	4	89	0	50
1999						
Shrike	Kesterson	5	6	100	0	100
Kestrel	Kesterson	10	5.1	66	0	70
Kestrel	Off-site	4	5.5	88	0	100
Barn owl	Kesterson	6	7.6	50	0	50

TABLE 5-1
Reproduction in Kestrels and Barn Owls Using Nest Boxes On and Off Kesterson Reservoir, 1998 – 2000.

Species	Nest Location	Number of Nests[a]	Mean Clutch Size	% Incubated Eggs Hatched	% Developmental Abnormalities	% Successful[b] Nests
2000						
Shrike	Kesterson	9	4.6	62	0	67
Kestrel	Kesterson	6	4.8	95	0	83
Kestrel	Off-site	2	4.5	50	0	50
Barn owl	Kesterson	5	3.6	56	0	60

[a] Includes nest boxes with multiple nests.
[b] One or more chicks fledged.
[c] Nests were found after eggs had hatched.

Five of the six barn owl nest boxes on Kesterson were used during 2000 (83 percent occupancy). Two were located in interior locations (Ponds 1 and 3), two were located along the perimeter road, and one was located in the compound off of Gun Club Road on the west side of Kesterson (Figure 5-1). Two of the interior nest boxes and the nest box in the compound successfully fledged chicks (60 percent nest success), whereas the two nest boxes along the perimeter road in Trisection 3 failed during egg-laying. No developmental abnormalities were observed in barn owl chicks or in embryos of collected eggs.

Nine loggerhead shrike nests were found (in or adjacent to Ponds 1, 3, 4, 6, 7 [2], 12, and two along the drain road south of Pond 1); four of the nest attempts were successful and fledged their young (44 percent nest success; Ponds 1, 3, 4, 6). Nest failure in all cases appeared to be due to egg-predation as the nests were found empty before the estimated hatch date and, in one nest, a damaged egg was found. Due to the short brooding period (≈ 16 days) and the potential increased risk of predation that can be caused by frequent visits to the nests, shrike chicks were only sampled once at about 7 days of age.

5.4.2 Selenium Concentrations

There was no significant difference between blood selenium concentrations in nesting adult kestrels, barn owls, and shrikes from Kesterson in 2000. Egg selenium and nestling blood selenium concentrations for all three species was significantly lower in 2000 than in 1999.

Among the species studied in 2000, selenium concentrations in eggs, nesting adults, and young at Kesterson were similar. In other years, differences in selenium concentrations among species were observed. Monitoring results from 2000 indicate that all species had similar levels of exposure to selenium.

There was only a poor relationship for parent blood selenium and egg selenium for kestrels and loggerhead shrikes ($r^2 < 0.01$, $P > 0.9$ for both species) and a somewhat better relationship for barn owls ($r^2 = 0.32$, $P = 0.088$) (See Table 5-2). The relationship between parent and nestling blood selenium was better for kestrels ($r^2 = 0.31$, $P = 0.014$) and shrikes ($r^2 = 081$, $P = 0.036$) than for barn owls ($r^2 = 0.23$, $P = 0.226$), possibly due to differences in foraging range (i.e., smaller ranges having less variable dietary selenium levels). Blood selenium is sensitive to relatively short-term changes in dietary exposure and this may be the reason for the poor relationship observed between parent blood-Se and egg selenium.

Kestrels were typically sampled after egg-laying had been completed to avoid disrupting reproduction and shrikes were typically captured within their breeding territory before nesting had begun. However, barn owls were usually sampled during the egg-laying period. Nestlings were typically sampled at least half way through the brooding period (e.g., two to three weeks after hatching for kestrels). The relationship between egg selenium and blood selenium in nestlings was weak in kestrels ($r^2 = 0.09$, $P = 0.259$) and strong in shrikes ($r^2 = 0.80$, $P < 0.001$) and barn owls ($r^2 = 0.51$, $P = 0.014$). There was a relationship between nestling and parent blood selenium in all three species but it was strongest in shrikes.

For kestrels observed during 2000, egg selenium was lower than either parent or nestling blood-Se and the variability in blood-Se among siblings was generally low (Table 5-3).

TABLE 5-2
Selenium Concentrations (μg/g, dry weight) in Parent and Nestling Kestrel, Barn Owl, and Loggerhead Shrike Blood and Eggs, 1998 – 2000

		Parent Blood Se[a]			Nestling Blood Se[b]			Egg Se[c]		
Species	Nest Location	*n*	Range	GM	*n*	Range	GM	*n*	Range	GM
1998										
Kestrel	Kesterson	9	2.4-24	6.7	4	2.7-28	6.1	4	2.3 – 5.0	3.4
Kestrel	Off-site	3	7.5-10	8.7	1		5.6	2	2.2-3.5	2.8
Barn owl	Kesterson	3	3.6-5.6	4.4	3	3.5-8.1	4.8	4	2.4-6.7	3.4
Shrike	Kesterson				5	7.5 – 25	12	4	4.5 – 6.0	5.3
Shrike	Off-site				2	1.7 – 1.9	1.8			
1999										
Kestrel	Kesterson	11	1.8 – 9.3	5.1	23	3.8 – 26	7.9	5	3.3 – 11	6.9
Kestrel	Off-site	4	1.5 – 4.8	2.9	13	2.1 – 4.4	3.2			
Barn owl	Kesterson	4	5.7 – 12	7.7	22	3.9 – 10	6.3	6	4.1 – 11	5.3
Shrike	Kesterson	3	10 – 20	14	21	5.3 – 21	13	5	3.0 – 14	8.2
2000										
Kestrel	Kesterson	6	2.7 – 13.5	7.7	16	1.8 – 11.2	4.8	4	2.7 – 3.5	2.9
Kestrel	Off-site	1		5.2	4	6.9 – 10.4	8.6			
Barn owl	Kesterson	5	1.7 – 9.1	5.6	10	4.0 – 6.1	4.9	5	1.8 – 4.9	2.8
Shrike	Kesterson	4	7.0 – 11	9.2	17	3.5 – 13.6	5.8	7	1.6 – 4.6	2.9

[a] Earliest sample taken during the nesting season.
[b] Data shown for about two weeks of age in kestrels, three weeks of age in barn owls, and one week of age in shrikes.

TABLE 5-3
Blood-Se (μg/g, dry weight) in Kestrels Using Nest Boxes On and Off Kesterson Reservoir, 2000

		Blood-Se	
Nest Box/Chick ID	Egg-Se	Parent[a]	Nestling (pooled)
NB 01-03	2.7	11.4	(4.9)
48117			4.8
48118			5.0
NB 02-02		2.7	(1.9)
48122			2.1
48123			2.0
48124			1.8
NB 04-02		7.7	
NB 05-01	2.8	6.7	(3.7)
48119			3.4
48120			3.6
48121			4.0
NB 09-02	3.5	9.9	(5.3)
48113			5.4
48114			5.5
48115			5.2
48116			5.2
NB 11-01	2.7	13.5	(10.2)
48109			10.1
48110			11.2
48111			9.6
48112			9.9
NB 140-01	2.0	5.2	(8.6)
48105			6.9
48106			8.5
48107			8.8
48108			10.4

[a] Parent blood-Se is the earliest sample taken during nesting.

5.5 Discussion

The 2000 nesting season appeared to have normal abundance of prey for avian predators based on the amount of small mammal sign and the number of small mammals found stashed inside nest boxes during observations. Among kestrel pairs that successfully laid eggs in this study, hatchability and fledging success were higher at Kesterson than in offsite areas. Adult kestrel mortality or abandonment was responsible for the early nesting failure on Kesterson. Dietary selenium levels in kestrels approximately equals blood selenium (Yamamoto et al. 1998). Because blood selenium levels in nesting kestrels at Kesterson (7.7 $\mu g/g$) are not in the range to cause adult mortality (10 - 15 $\mu g/g$ dietary exposure [NIWQP 1998]), mortality was not believed to be directly attributable to selenium exposure. Similarly, the barn owl nest failures were not likely to have been selenium-caused, based on nesting adult barn owl blood selenium levels in 2000 (5.6 $\mu g/g$). The lack of use of the barn owl nest in the Pond 5 nest box may have been due to design of the box, which is not as deep as other boxes and may allow predators such as great horned owls to reach in and capture the chicks. Loggerhead shrikes had similar egg and blood selenium levels as other species, and had 100 percent hatchability and fledging success in the four nests that were successful (not lost to predation). None of the eggs had selenium concentrations that were above a suggested avian threshold for reproductive impairment of 10 $\mu g/g$ (Heinz 1996) and no developmental abnormalities were found in either Kesterson or offsite nests. This result is in agreement with previous nest monitoring data for other terrestrial species at Kesterson.

Occupancy of nest boxes by kestrels in 2000 was 20 percent, lower than occupancy observed in 1999 (30 percent). The failed kestrel nest was abandoned (NB 04-02) after only one egg was laid, but the fate of the adults from this nest is not known. The higher occupancy observed during the 1999 reproductive season may have been partly due to the unusually high prey abundance observed during that year (CH2M HILL 2000), which was not evident during the 2000 monitoring period.

Although prey abundance seemed adequate during 2000, prey abundance appeared to be lower than in 1999, when the prey-base seemed higher than normal (based on observations made during monitoring) and consequently foraging ranges probably were larger, especially during the brooding and fledging periods when food demands are typically higher. This may have caused more offsite foraging and therefore, lower dietary selenium exposure. Higher selenium concentrations in 1999 predatory birds nesting at Kesterson may have been partly due to the high prey abundance during the nesting season. Nesting birds may have reduced their foraging range because they did not need to travel off Kesterson as much to find prey and may have had a diet higher in selenium. On average, blood selenium concentrations in the nesting kestrels (7.7 $\mu g/g$) was slightly higher than the overall mean for nonbreeding kestrels trapped from 1994-1998 in Kesterson (5.0 $\mu g/g$, dry weight; Santolo and Yamamoto 1999). These concentrations are below those observed in kestrels fed a dietary Lowest Observed Adverse Effect Level (LOAEL) of 12 $\mu g/g$ selenium (Yamamoto and Santolo 2000), and are not expected to be associated with adverse effects in wild kestrels (Santolo et al. 1999). Compared with other predatory bird species sampled at Kesterson, kestrels tend to be similar in selenium accumulation to red-tailed hawks, but lower than barn owls, northern harriers, and loggerhead shrikes. These species differences are probably in large part due to differences both in relative amount of time spent foraging at Kesterson

and to prey species selection. In years such as 1999, when the prey base in Kesterson is high, selenium concentrations can be expected to be higher because the need to forage off-site (farther from the nest) is reduced.

No relationship was observed between blood selenium concentrations in parent birds and selenium concentrations in eggs of kestrels at Kesterson in 2000. This was different than data from captive kestrels indicating an approximate blood-to-egg transfer factor range of 1.7-2.8 (Santolo et al. 1999). Both barn owls and shrikes showed a stronger relationship between parent blood selenium and egg selenium. This was probably due to the timing of sampling in barn owls and the less variable dietary selenium exposure in shrikes (possibly due to the smaller foraging range of shrikes). Due to the variability inherent in the blood selenium concentrations of wild birds, it is unlikely that this relationship can be verified in the field for kestrels with opportunistic, single blood samples (from parent birds) that are not closely timed with egg-laying. Compared with other bird species sampled at Kesterson, kestrels exhibited slightly lower selenium accumulation in eggs (mean for all bird eggs sampled in 2000 = 2.9 $\mu g/g$ selenium, dry weight). For the barn owl nest box birds, the ratio of blood-to-egg selenium (about 0.5) was higher than the ratio for kestrels (about 0.4) and for shrikes (about 0.3). This was below the blood-to-egg transfer factor found in captive kestrels fed selenomethionine (Santolo et al. 1999).

In typical years, Kesterson may not provide adequate resources to support greater numbers of nesting kestrels than were found during the 1998 and 2000 nesting seasons and the baseline density may be about six pairs. Some of the potential limiting factors for occupancy include habitat quality, intraspecific food competition, interspecific nest box competition (commonly observed at Kesterson between kestrels and starlings), and disturbance.

5.6 References

CH2M HILL. 1996. *Kesterson Reservoir 1996 Biological Monitoring Report*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

CH2M HILL. 1998. *Kesterson Reservoir 1998 Biological Monitoring Report*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

CH2M HILL. 2000. *Kesterson Reservoir 1999 Biological Monitoring Report*. Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

Craft, R. A., and K. P Craft. 1996. "Use of free ranging American kestrels and nest boxes for contaminant risk assessment sampling: A field application." *Journal of Raptor Research* 30:207-212.

Grue, C. E. and C. L. Christian. 1981. "Use of captive starlings to determine effects of pollutants on passerine reproduction." In *Avian and Mammalian Wildlife Toxicology: Second Conference*. ASTM STP 757. D.W. Lamb and E.E. Kenaga, Eds., American Society for Testing and Materials. Pp. 5-18.

Heinz, G. H. 1996. "Selenium in birds." In *Environmental Contaminants in Wildlife: Interpreting Tissue Concentrations*. W. N. Beyer, G. H. Heinz and A. W. Redmon-Norwood, Eds., Lewis, New York, NY. Pp. 447-458.

Marti, C.D. 1992. "Barn owl (*Tyto alba*)." In *The Birds of North America, No. 1.* A. Poole and F. Gill, Eds., Philadelphia: The Academy of Sciences; Washington, DC: The American Ornithologists Union.

National Irrigation Water Quality Program (NIWQP). 1998. *Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment.* USDI National Irrigation Water Quality Program. Information Report No. 3. November, 1998.

Santolo, G. M. and J. T Yamamoto. 1999. "Selenium in blood of predatory birds from Kesterson Reservoir and other Areas of California." *Journal of Wildlife Management* 63:1273-1281.

Santolo, G. M., J. T. Yamamoto, J. M. Pisenti, and B. W. Wilson. 1999. "Selenium accumulation and effects on reproduction in captive American kestrels fed selenomethionine." *Journal of Wildlife Management* 63:502-511.

Yamamoto, J. T. and G. M. Santolo. 2000. "Body condition effects in American kestrels fed selenomethionine." *Journal of Wildlife Diseases* 36:646-652.

Yamamoto, J. T., G. M. Santolo, and B. W. Wilson. 1998. "Selenium accumulation in captive American kestrels (*Falco sparverius*) fed selenomethionine and naturally incorporated selenium." *Environmental Toxicology and Chemistry* 17:2494-2497.

SECTION 6

Selenium in Wild Birds

6.1 Introduction

In 1988, wetland habitats that supported a variety of waterfowl and shorebirds at Kesterson were converted to upland habitats that support a variety of terrestrial bird species. Very little is known about effects of selenium on free-living species of terrestrial birds. The early successional habitat at Kesterson supports plant, invertebrate, and vertebrate prey items utilized by terrestrial birds. Although some information was collected on nonpredators, including killdeer, sparrows, meadowlarks, and starlings, this study focused on predatory birds. Avian predators are potentially good terrestrial indicator species because they are common at Kesterson, their foraging ranges can be estimated, and selenium concentrations are relatively high in vertebrate and invertebrate prey compared to plants. Also, many are easily studied throughout the breeding season because they are tolerant of disturbance and they have long development and nestling stages. Avian predators may be sensitive to selenium at dietary levels found at Kesterson (i.e., lower fertility, Santolo et al. 1999; decreased body condition, Yamamoto and Santolo 2000), based on studies using captive American kestrels. However, studies with captive and wild birds (e.g., Heinz 1996, NIWQP 1998) suggest that sensitive aquatic species (e.g., mallards and black-necked stilt) accumulate and transfer selenium to eggs to a greater degree than do some carnivorous species (e.g., black-crowned night-herons [*Nycticorax nycticorax*; Smith et al. 1988], screech-owls [*Otus asio*; Wiemeyer and Hoffman 1996], and American kestrels (Yamamoto et al. 1998).

During 2000, fewer adult and juvenile birds were trapped on Kesterson and other trapping sites than in 1995, 1996, and 1997 (G. M. Santolo, unpublished trapping results 1995–2000). This was probably due to the low nesting population observed at Kesterson and in other areas of California during 1997 and 1998 (CH2M HILL 1998), which has been corroborated by fewer wintering juvenile red-tailed hawks being observed in the Central Valley (A. Morzenti, UC Davis, personal communication and G. Santolo, unpublished survey data). For example, red-tailed hawks and other raptor species are most abundant in the Central Valley during the fall and winter months, but only a small number of adult and juvenile red-tailed hawks were observed at Kesterson during the fall and winter of the last three years compared to most other years, when daily use was monitored at Kesterson, and especially when compared to years of high abundance such as 1994 – 1995 (Figure 6-1).

A previous risk assessment for Kesterson produced exposure models that predicted selenium concentrations in various biota, including the diets of red-tailed hawks and northern harriers, over a 20-year period (Ohlendorf and Santolo 1994, Santolo 1994). This model was based primarily on known concentrations of selenium in prey species as well as on estimated time spent foraging at Kesterson. Predicted selenium concentrations in the diets of these avian predators were not expected to be high enough to cause significant risks. However, few measurements of selenium in these species were available at the time to develop model predictons. Wild predatory birds were sampled at Kesterson and other

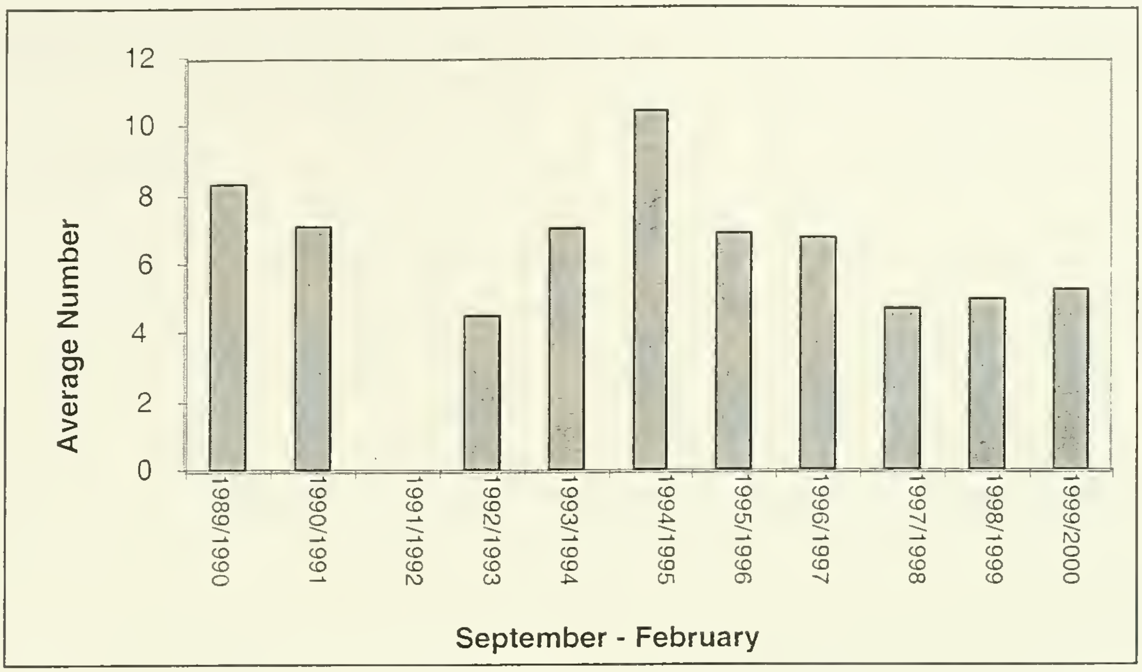


FIGURE 6-1
Fall and Winter Red-tailed Hawk Use of Kesterson, 1989 – 2000

locations in California to better characterize the exposure of these and other terrestrial birds to selenium, and to verify prior exposure model predictions for Kesterson.

6.2 Objectives

The objectives of this study were to identify the selenium levels in the blood of wild birds found at Kesterson, and to compare the levels found at Kesterson to blood levels found in other areas of California.

For comparison to Kesterson, birds from three other areas of California were sampled. These study areas included:

- Lands surrounding Kesterson ("Kesterson Area"), for an approximate 16-km radius (generally bounded by the Cities of Stevinson, Gustine, Los Banos, and Santa Nella), that contain primarily agricultural lands (row crops, orchards, and pasture) and seasonal wetland habitats. Some of these pastures and seasonal wetland habitats had historically been irrigated with selenium-containing agricultural drainwater (Presser and Barnes 1985)
- Areas located approximately 200 km north of Kesterson in the counties of Yolo, Solano, and San Joaquin ("Sacramento Valley"; 38°N, 121°W)
- Areas approximately 130 km northwest of Kesterson near Suisun Marsh ("Bay–Delta"; 38°N, 122°W)

Except for the Bay–Delta study area (which was mostly wetland), habitats in these areas were mostly agricultural, similar to those of the Kesterson Area. During November 1995, American kestrels were sampled from a fourth area located in agricultural areas adjacent to

the Salton Sea (Imperial County), located in the Imperial Valley of California, approximately 1,100 km south of Kesterson (33°N, 115°W).

6.3 Methods

6.3.1 Field Sampling and Selenium Analysis

Year-round trapping efforts were carried out during the 1994 to 1999 study period. Samples were collected in all months except January, March, and April 1994, February and March 1995, February and June 1996, September 1997, and August and September 1998. In 1999 and 2000, blood samples were collected from adult birds during January, March through May, and June (2000) and July (1999). Species sampled were barn owl, red-tailed hawk, American kestrel, and loggerhead shrike. A limited number of samples were collected from other species, which will be discussed later. In addition to adult and immature birds, nestlings of kestrels, loggerhead shrikes, and barn owls were sampled and are discussed in the section, *Predatory Bird Nesting Study*. Searching for birds to trap was done primarily from a vehicle. Birds were captured with a bal-chatri or modified Potter's trap using live mice as lures, and a dho-ghaza trap, using a great horned owl as a lure for nesting birds (Bub 1991). Bal-chatri traps were used in trapping attempts for birds that were considered capable of seeing a trap (up to about 100 m from the road) thrown from the vehicle onto the road shoulder. Sparrows were trapped using a walk-in treadle trap baited with seed. After capture, birds were weighed and, when possible, aged and sexed and fitted with a federal (aluminum) band. Up to 0.5 mL of blood was drawn from a wing or jugular vein using a heparanized 1 mL insulin syringe. European starlings were captured in nest boxes and a blood sample was drawn from the jugular vein. Western meadowlarks and killdeer were collected with a shotgun and a blood sample was taken from the heart using a heparanized syringe. Blood was stored in 3 mL cryogenic vials (Nalgene, Inc.) and frozen < -40° C for selenium analysis. All measurements and blood sampling were done at the capture site, and birds were released immediately after processing was complete.

6.3.2 Laboratory Analyses

Whole blood samples were analyzed for total selenium by two commercial laboratories. At Laboratory and Environmental Testing (LET, Columbia, Missouri), sample preparation consisted of lyophilization, followed by homogenization, and sequential acid digestions (nitric acid followed by hydrochloric acid). Total selenium concentrations were determined using hydride generation atomic absorption spectroscopy. Quality control included at least 10 percent duplicates, 10 percent spikes, 5 blanks, and 5 percent reference samples. Lyophilization data were used to calculate percent moisture in all samples. The California Veterinary Diagnostic Laboratory (CVDLS, Davis, California) used hydride vapor generation inductively coupled argon plasma spectrometry (Tracy and Möller 1990). Twenty duplicate samples were analyzed and compared between laboratories. A linear regression analysis produced an r^2 value of 0.96 ($P < 0.0001$) for the duplicate samples, indicating that results were comparable between laboratories and analytical techniques. All selenium concentrations in blood are expressed as $\mu g/g$ on a dry weight basis.

6.4 Results and Discussion

6.4.1 Capture Frequencies of Predatory Birds

Numbers of individuals captured from 1994 to 1998 are described in Santolo and Yamamoto (1999). In 2000 as in 1999, few species were represented in birds captured away from Kesterson (Table 6-1) and many of the adult birds sampled at Kesterson were nesting birds. After a bird is captured once, it becomes more difficult to recapture because it is reluctant to approach the trap. However, because some adult red-tailed hawks, American kestrels, barn owls, as well as most loggerhead shrikes may remain at Kesterson throughout the year, some of the birds may have been captured in previous years.

TABLE 6-1
Blood-Se Concentrations (μg/g dry weight) for Adult Birds Collected From Various Locations in California. Number of Samples (*n*), Range of Blood-Se (Range), and Geometric Mean Selenium Concentrations (GM) are Shown.

	1994 – 1999			2000		
Species and Location	*n*	Range	*GM*	*n*	Range	GM
American kestrel						
Kesterson	73	1.8 – 31	5.2	5	2.7 – 14	7.7
Kesterson Area	61	1.0 – 6.8	2.3	3	1.3 – 5.2	2.7
Salton Sea	14	1.6 - 4.1	2.5			
Sacramento Valley	15	1.9 – 7.3	3.3			
Bay–Delta	5	1.5 – 2.5	1.9			
Red-tailed hawk						
Kesterson	44	2.1 – 8.7	3.9			
Kesterson Area	33	1.6 – 4.7	2.6			
Sacramento Valley	11	2.0 – 4.1	3.0			
Bay–Delta	4	1.9 – 2.9	2.4			
Northern harrier						
Kesterson	6	6.3 - 15	9.4			
Sacramento Valley	2	2.0 - 3.8	2.8			
Barn owl						
Kesterson	97	1.5 – 12	4.6	5	1.7 – 9.1	5.6
Kesterson Area	16	1.7 – 5.2	2.4			
Sacramento Valley	7	3.0 – 3.8	3.3			
Other owls						
Kesterson	3	6.1 – 11	8.7			
Sacramento Valley	2	3.5 – 4.5	4.0			
Killdeer						
Kesterson	5	7.6 – 57	30	1		38
Loggerhead shrike						
Kesterson	28	4.9 – 38	12	2	7.0 – 11	8.7
Kesterson Area	9	5.8 – 16	8.3			
Sacramento Valley	7	2.4 – 6.1	3.5	6	2.4 – 6.5	3.9
Bay–Delta	7	2.5 - 3.7	3.1			

TABLE 6-1
Blood-Se Concentrations (μg/g dry weight) for Adult Birds Collected From Various Locations in California. Number of Samples (*n*), Range of Blood-Se (Range), and Geometric Mean Selenium Concentrations (GM) are Shown.

	1994 – 1999			2000		
Species and Location	*n*	**Range**	*GM*	*n*	**Range**	**GM**
Western kingbird						
Kesterson	1		64			
European starling						
Kesterson	33	2.8 – 19	5.9			
Western meadowlark						
Kesterson	8	7.8 – 18	12			
White-crowned sparrow						
Kesterson	6	7.4 – 33	18			

Note: Mean of percent moisture in blood samples was 80.8% and ranged from 67.6 to 91.0% in samples collected from 1994 – 1999, and 71.0 to 81.0 % in 2000.

Both individual and combined species blood-Se data are in agreement with monitoring data from Kesterson showing consistently high levels of selenium in raptor prey species (Table 6-2; Note that potential prey species were not sampled in 1999 or 2000 but will be sampled in 2001). Reported background selenium concentrations in mammals (whole body) average < 2 μg/g (NIWQP 1998). Blood-Se of avian predators should be approximately equal to concentrations of selenium in their diet, based on data from captive kestrels fed either pure selenomethionine mixed into the diet or small mammals collected at Kesterson (Yamamoto et al. 1998), and from captive screech-owls fed selenomethionine (Wiemeyer and Hoffman 1996). The result of blood selenium analysis of wild birds is consistent with captive studies and results of radiotelemetry studies on the amount of foraging on and off Kesterson. The geometric mean blood-Se concentrations for all adult and juvenile avian predators sampled at Kesterson for 1994 (4.5 μg/g), 1995 (5.1 μg/g), 1996 (4.2 μg/g), 1997 (5.1 μg/g), 1998 (6.4 μg/g), 1999 (7.2 μg/g), and 2000 (5.7 μg/g) were slightly lower than the geometric mean selenium concentration of small mammals collected from Kesterson in 1994 (6.7 μg/g), 1995 (5.9 μg/g), 1996 (7.1 μg/g), and 1998 (7.1 μg/g; whole body selenium [Table 6-2]).

TABLE 6-2
Total Selenium Concentrations (μg/g, dry weight) in Potential Prey Species of Predatory Birds at Kesterson. Analyses Were for Whole Animals. Sample Sizes (*n*), Range of Whole-Body Selenium Concentration (Range), and Geometric Mean Selenium Concentrations (GM) are Shown.

	1994 – 1996			1998		
Species	*n*	**Range**	**GM**	*n*	**Range**	**GM**
Invertebrates	*387*	*0.60 – 48*	*10*	*137*	*1.8 – 61*	*14*
Beetle	167	0.60 - 41	13	64	4.2 – 61	17
Cricket	34	2.3 - 26	7.8	4	3.9 – 24	12
Grasshopper	107	1.3 - 22	5.8	34	1.8 – 17	7.3
Spider	79	4.5 - 48	14	35	8.1 – 36	17

TABLE 6-2
Total Selenium Concentrations (μg/g, dry weight) in Potential Prey Species of Predatory Birds at Kesterson. Analyses Were for Whole Animals. Sample Sizes (*n*), Range of Whole-Body Selenium Concentration (Range), and Geometric Mean Selenium Concentrations (GM) are Shown.

	1994 – 1996			1998		
Species	*n*	Range	GM	*n*	Range	GM
Mammal	*262*	*0.23 – 131*	*6.0*	*86*	*0.63 – 35*	*7.1*
Deer mouse	71	1.3 - 131	6.8	30	2.0 – 19	6.7
Western harvest mouse	19	4.0 - 15	7.9	17	2.4 – 20	7.7
House mouse	31	2.2 - 22	8.3	31	0.71 – 35	7.9
Ornate shrew	1		18	1		7.5
California vole	79	0.32 - 26	5.3	7	0.63 – 16	4.4
Desert cottontail	27	0.23 - 11	3.6			
California hare	15	0.4 - 18.9	4.3			
California ground squirrel	19	2.1 - 44	7.1			

Note: Small mammal samples were collected from Kesterson in 1994, 1995, 1996, and 1998. Invertebrate samples were collected only in 1994, 1995, and 1998. No invertebrate samples were collected in 1996 and no small mammals or invertebrates were collected in 1997.

The accumulation of selenium in the blood of kestrels from dietary sources (an approximate 1:1 relationship) is less than that reported in mallards, in which blood-Se plateaued at about 3 to 4 times the experimental dietary concentrations of 10 and 20 μg/g (Heinz and Fitzgerald 1993). In captive kestrel studies, a log-linear relationship was observed between selenium concentration in the diet and blood selenium concentrations (Yamamoto et al. 1998). This relationship is described by the equation:

$$\text{log blood-Se} = 0.34 + 0.552\ (\text{log diet-Se}) \qquad \textbf{Equation 6-1}$$

Based on this equation, expected blood-Se from avian predators feeding only on small mammals at Kesterson in 1998 would have been 6.4 μg/g (1.7 – 15.6 μg/g) and in 1999 would have been 2.6 μg/g (0.66 – 11.9 μg/g).

Using small mammal selenium concentrations it was possible to predict blood selenium concentrations in predatory birds at Kesterson (Table 6-3). However, these predictions do not take into account offsite foraging and dietary items other than mammals (e.g., invertebrates) and therefore they predicted higher selenium concentrations than were actually measured. Using a more complex food chain model based on: 1) Kesterson monitoring data (weighted by habitat type); 2) field and laboratory studies; and 3) the results of the 1998 soil sampling for selenium (the last year soil samples were collected for selenium analysis), kestrels at Kesterson in 1998 (feeding 60 percent on-site) would be expected to have a range of mean blood-Se concentrations from 1.6 μg/g to 5.7 μg/g (CH2M HILL 2000b).

TABLE 6-3
Predatory Bird Measured and Blood-Se Concentrations (μg/g, dry weight) Predicted from Selenium Concentrations of Whole Animals Trapped at Kesterson. Sample Sizes (*n*), Range of Whole-Body Selenium Concentration (Range), and Geometric Mean Selenium Concentrations (GM) are Shown.

	Measured Blood-Se			Predicted Blood-Se		
Species	*n*	Range	GM	*n*	Range	GM
1994	91	1.5 – 15	4.5	85	1.2 – 33	6.2
1995	31	1.9 – 15	5.1	105	2.5 – 16	5.9
1996	37	2.0 – 14	4.2	27	3.2 – 12	6.5
1998	108	1.5 – 38	5.9	86	1.7 – 16	6.4
1999	159	1.7 – 26	7.2	38	2.3 – 12	5.6

Note: Small mammal samples were collected from Kesterson in 1994, 1995, 1996, 1998, and 1999 (CH2M HILL 2000c). Invertebrate samples were collected only in 1994, 1995, and 1998. No invertebrate samples were collected in 1996, and no small mammals or invertebrates were collected in 1997.

6.4.2 Comparison of Blood-Se of Species at Kesterson

Comparing geometric mean blood-Se among species at Kesterson, the selenium concentration in the single killdeer sampled was similar to the mean selenium concentration in killdeer sampled during 1998, and it had the highest concentration of any bird sampled at Kesterson in 2000 (Table 6-1). General factors contributing to species differences in blood-Se probably include relative time spent foraging at Kesterson, which is influenced by both seasonal movements and home range characteristics; dietary composition (various dietary items contain differing concentrations of selenium [see Table 6-2]); and species-specific differences in selenium metabolism. Kesterson monitoring data from this and other years suggest that home range is an important factor in determining selenium exposure. Birds with small home ranges captured onsite are likely to be foraging in the area they were captured. Those with large home ranges are spending some (unknown) portion of time foraging were they were captured.

Based on previously reported home ranges for shrikes and raptors (Preston 1990), and on observations of these and other species at Kesterson, the highest blood-Se levels observed in passerines are probably due in large part to these birds spending relatively more time foraging at Kesterson. Shrikes maintain relatively small home ranges (about 8.5 ha in California; Miller 1931) and those at Kesterson do not seem to be migratory. This suggests that individuals captured at Kesterson spend a large part of their time within this area. Similarly, the blood-Se data obtained from both nesting and wintering passerines reflect individuals foraging for extended periods of time primarily at this site. Other species in past years, such as northern harriers, have also exhibited high blood-Se at Kesterson (Santolo and Yamamoto 1999), especially nesting individuals. Harriers in particular may be able to utilize interior portions of Kesterson to a greater extent than some other raptors, due to their preferred hunting method of low coursing over foraging terrain. There are no trees and few artificial structures in the interior areas of Kesterson, and predatory birds that rely primarily on perch-hunting (such as red-tailed hawks, kestrels, and owls) tend to forage on the periphery of Kesterson where power poles and fence posts offer ample perching sites. For

these species, this behavior most likely results in varying degrees of foraging outside of Kesterson, thus moderating selenium intake from prey items within Kesterson. These perches have been limited by removal of the poles along the San Luis Drain from Pond 7 to Pond 12.

Since the removal of aquatic habitat in 1988, routine biological monitoring, as well as a European starling nest-box study conducted in 1995, have revealed no evidence of reproductive effects in terrestrial birds at Kesterson, though data on nesting raptors are few. However, kestrel and barn owl nest-box studies now in progress at Kesterson have provided more detailed information on whether current selenium concentrations pose a threat to reproduction of terrestrial birds. At this time, kestrels, shrikes, and barn owls appear to have similar nesting success at Kesterson as they do in other areas of California (i.e., the Sacramento Valley and San Clemente Island [shrikes]; personal communication Peter Bloom, Western Vertebrate Museum and Nils Warnock, Point Reyes Bird Observatory).

6.4.2.1 Comparison of Blood-Se in Re-trapped Adult Birds

Thirty birds were sampled more than once at Kesterson during the course of this study (Table 6-4). Within individuals there was no consistent trend in selenium concentration over time and blood-Se was observed to decrease, increase, or remain stable between initial and subsequent samples. No seasonal differences were found in this limited data set. Five kestrels were sampled twice within one month during the nesting period, and all exhibited variable increases in blood-Se by the second sample time as did the single shrike that was re-sampled within a month. Two barn owls sampled twice during a one-month period both exhibited lower blood-Se concentrations. Fifteen kestrels were resampled from 7 to 20 months after initial sampling, 33 percent of the samples were higher (from 2.0 to 25 $\mu g/g$), 47 percent were lower (from 1.4 to 7.7 $\mu g/g$), and 20 percent had blood-Se nearly equal to their initial level. Of four barn owls resampled between 6 and 12 months after their first sample, one increased by 2.6 $\mu g/g$, one decreased by 4.5 $\mu g/g$, and two showed no change. Of four shrikes resampled after 8 to 20 months, three had decreased blood-Se (from 1.4 to 23 $\mu g/g$) and one showed no change. Large variations in blood-Se within individuals are probably attributable to changes in prey selection and availability over time, as well as a high degree of temporal and spatial fluctuation in soil selenium affecting bioavailability (Wahl et al. 1994), and therefore prey concentrations, at Kesterson (see Table 6-2). In addition, because dietary selenium is relatively quickly absorbed into the blood, blood-Se measurements are especially sensitive to recent exposure levels and therefore variable. Most resampled birds were birds nesting (either year-round or seasonally resident) on Kesterson and foraging over 40 percent in areas adjacent to Kesterson where selenium concentrations found in birds sampled (other than shrikes) have been near reference levels (see *Nest Box and Telemetry Study*). Blood-Se was generally consistent with the presumed resident status of re-sampled birds, in that most samples were at least twice background in selenium concentration (NIWQP 1998).

TABLE 6-4
Blood-Se (Se; μg/g dry weight) and Date of Sampling (Date) in American Kestrels, Barn Owls, and Loggerhead Shrikes from Kesterson Sampled More Than Once.

	Initial		1 Month		≥ 1 Month < 1yr		1yr+		2yr	
ID	Date	Se	Se	Date	Se	Date	Se	Date	Se	Date
American kestrel										
900	21 Mar 99	5.3			5.3	09 May 99	13.5	16 Apr 00		
220	29 Mar 97	2.7					2.6	20 Dec 98		
231	17 May 97	5.1			12.4	18 Apr 98	14.3	02 May 98		
240	7 Jun 97	11.6			6.4	05 Apr 98	4.7	09 May 98		
251	2 Nov 97	6.8			6.8	25 Apr 98	31.1	30 May 98		
252	2 Nov 97	5.7			2.9	25 Apr 98				
271	5 Apr 98	9.6	17.2	09 May 98	3.1	03 Jan 99				
274	5 Apr 98	10.0	12.1	19 Apr 98	2.2	20 Dec 98	3.6	21 Mar 99	4.8	04 Apr 99
275	18 Apr 98	4.9	5.3	09 May 98						
277	19 Apr 98	7.5			2.9	11 Apr 99				
105	20 Dec 98	3.3			5.3	05 Mar 99				
114	24 Jan 99	1.8			6.2	31 May 99				
117	24 Mar 99	6	6.5	24 Apr 99						
123	24 Apr 99	4.9			3.5	04 Jul 99				
133	02 May 99	4.1			4.2	12 Dec 99				
162	04 Dec 99	10.9			7.7	30 Apr 00				
163	04 Dec 99	2.4			2.7	17 Jan 00				
170	12 Dec 99	4.7	5.3	19 Dec 99						
Barn owl										
584	11 Nov 94	6.1					3.6	30 May 98	8.0	03 Jan 99
503	4 Jul 95	5.1					4.9	18 May 96	3.8	10 May 97
515	02 Sep 94	1.8			2.3	01 Mar 95				
577	30 May 98	5.6			6.9	30 Jan 99	8.2	04 Apr 99	9.1	02 Apr 00
589	28 Mar 99	12.2	7.7	04 Apr 99			7.8	02 Apr 00		
590	28 Mar 99	5.7	4.8	04 Apr 99						

TABLE 6-4
Blood-Se (Se; μg/g dry weight) and Date of Sampling (Date) in American Kestrels, Barn Owls, and Loggerhead Shrikes from Kesterson Sampled More Than Once.

	Initial		1 Month		> 1 Month < 1yr		1yr+		2yr	
ID	Date	Se	Se	Date	Se	Date	Se	Date	Se	Date
Loggerhead shrike										
507	06 Jun 98	37.5			14.9	12 Dec 99				
524	04 Apr 99	9.4			9.5	19 Dec 99				
542	17 Apr 99	12.3			10.9	02 Jan 00				
812	7 Jun 97	20.0					11.0	28 Jun 98		
504	06 Jun 99	8.9	12.6	14 Jun 99						

Adult birds sampled at Kesterson during the nesting season (March through June; n = 132) had significantly higher selenium concentrations ($F_{3,312}$ = 19.98, P < 0.001) than those trapped in summer (July through September; n = 81), when birds are dispersing from their natal territories, and during migration in the fall (October through December; n = 77) or during the wintering period (January through February; n = 26; Figure 6-2). However, there is a great deal of variability because some individual kestrels, barn owls, and shrikes have been observed at Kesterson during all seasons and are probably year-round residents.

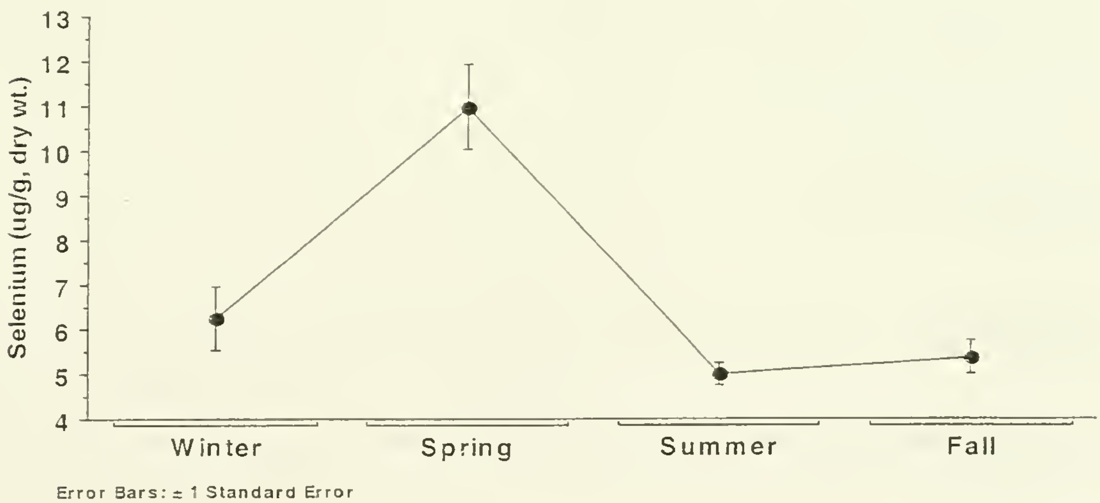


FIGURE 6-2
Seasonal Blood-Se in Birds from Kesterson, 1994 – 2000

Predatory birds at Kesterson exhibited variable but consistently elevated selenium concentrations in their blood relative to birds sampled in other areas of California (Table 6-1). Other bird species sampled at Kesterson (such as killdeer, starlings, meadowlarks, kingbird, and sparrows) also exhibited elevated blood selenium

concentrations (Tables 6-3 and 6-4) and probably reflect the smaller ranges in which they forage. Birds that utilize Kesterson and have larger foraging ranges (e.g., red-tailed hawks) feed both onsite and offsite and have a lower overall exposure than birds with small foraging ranges that may feed almost entirely within Kesterson. For example, kestrels and shrikes have similar diets, so the relatively lower blood-Se in kestrels than that found in shrikes may be due in large part to foraging range. Male kestrels nesting at Kesterson were found to forage off-site at least 40 percent of the time (CH2M HILL 2000a), whereas a shrike may spend all of its time foraging onsite. Similarly, winter flocks of white-crowned sparrows in California occupy ranges of 6 – 8 ha (Chilton et al. 1995), a range similar to that of shrikes in California, and once they are established in their wintering flock there is little movement to other flocks. Meadowlarks may also forage over fairly small (1.2 to 13 ha; [Lanyon 1994]) ranges, and they have similar blood-Se levels to shrikes and sparrows (Table 6-4). Based on these findings, and on previous studies with captive kestrels (Yamamoto et al. 1998), blood-Se appears to be a useful indicator of minimum dietary selenium exposure in predatory, and potentially other, terrestrial birds (Santolo and Yamamoto 1999). Comparative data will continue to help characterize species differences in exposure to selenium and associated risks, and identify critical determinants of selenium bioaccumulation in these birds.

6.5 References

Bub, H. 1991. *Bird Trapping and Bird Banding.* Cornell University Press. Ithaca, NY.

CH2M HILL. 1998. *Kesterson Reservoir 1998 Biological Monitoring Report.* Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

CH2M HILL. 2000a. *Kesterson Reservoir 1999 Biological Monitoring Report.* Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

CH2M HILL. 2000b. *Ecological Risk Assessment for Kesterson Reservoir.* Prepared for U.S. Bureau of Reclamation, Mid-Pacific Region, Sacramento, CA.

CH2M HILL. 2000c. *A Comparison of Small Mammals from Kesterson Reservoir and Three Nearby Sites.* Prepared for USBR, Mid-Pacific Region, Sacramento, CA.

Chilton, G., M.C. Baker, C.D. Barrentine, and M.A. Cunningham. 1995. "White-Crowned Sparrow *(Zonotrichia lencophrys).*" *Birds of North America,* No. 183. A. Poole and F. Gill, eds. The Birds of North America, Inc., Philadelphia, PA.

Heinz, G. H. 1996. "Selenium in birds." In *Interpreting Environmental Contaminants in Animal Tissues.* W.N. Beyer, G. H. Heinz and A. W. Redmon, eds. Lewis Publishers, Boca Raton, Florida. Pp. 447-458.

Heinz, G. H. and M. A. Fitzgerald. 1993. "Overwinter survival of mallards fed selenium." *Arch. Environ. Contam. Toxicol.* 25:90-94.

Lanyon, W.E. 1994. "Western Meadowlark (*Sturnella neglecta*)." *The Birds of North America,* No. 104. A. Poole and F. Gill, eds. The Birds of North America, Inc., Philadelphia, PA.

Miller, A. H. 1931. Systematic revision and natural history of the American shrikes (Lanius). *University of California Publications in Zoology* 38:11-242.

National Irrigation Water Quality Program (NIWQP). 1998. *Guidelines for Interpretation of the Biological Effects of Selected Constituents in Biota, Water, and Sediment.* USDI, National Irrigation Water Quality Program Information Report no. 3. 198 pp.

Ohlendorf, H. M., and G. M. Santolo. 1994. "Kesterson Reservoir- Past, present, and future: an ecological risk assessment." *Selenium in the Environment.* W. T. Frankenberger and S. Benson, eds. Marcel Dekker, New York, NY. Pp. 69-117

Presser, T.S., and I. Barnes. 1985. *Dissolved constituents including selenium in waters in the vicinity of Kesterson National Wildlife Refuge and the West Grassland, Fresno, and Merced Counties, California.* Water Resources Investigation Report, 85-4220, USGS. Menlo Park, CA.

Preston, C. R. 1990. "Distribution of raptor foraging in relation to prey biomass and habitat structure." *Condor* 92:107-112.

Santolo, G. M. 1994. Ecological risk assessment for Kesterson Reservoir, Merced County, California. Thesis, University of California, Davis, CA.

Santolo, G. M., J. T. Yamamoto, J. M. Pisenti, and B. W. Wilson. 1999. "Selenium accumulation and effects on reproduction in captive American kestrels fed selenomethionine." *Journal of Wildlife Management* 63:502-511.

Santolo, G. M. and J. T. Yamamoto. 1999. "Selenium in blood of predatory birds from Kesterson Reservoir and other areas in California." *Journal of Wildlife Management* 63:1273-1281.

Smith, G. J., G. H. Heinz, D. J. Hoffman, J. W. Spann, and A. J. Krynitsky. 1988. "Reproduction in black-crowned night-herons fed selenium." *Lake and Reservoir Management* 4:175-180.

Tracy, M. L., and G. Möller. 1990. "Continuous flow vapor generation for inductively coupled argon plasma spectrometric analysis." *Part 1: Selenium. Journal of the Association of Official Analytical Chemists* 73:404-410.

Wahl, C., S. Benson, and G. M. Santolo. 1994. "Temporal and spatial monitoring of soil selenium at Kesterson Reservoir, California." *Water, Air and Soil Pollution* 74:345-361.

Wiemeyer, S. J., and D. J. Hoffman. 1996. "Reproduction in eastern screech-owls fed selenium." *Journal of Wildlife Management* 60:332-341.

Yamamoto, J. T., G. M. Santolo, and B. W. Wilson. 1998. "Selenium accumulation in captive American kestrels (*Falco sparverius*) fed selenomethionine and naturally incorporated selenium." *Environmental Toxicology and Chemistry* 17:2494-2497.

Yamamoto, J. T. and G. M. Santolo. 2000. "Body condition effects in American kestrels fed selenomethionine." *Journal of Wildlife Diseases* 36:646-652.